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(54) **MEMOIZING WEB-BROWSING  
COMPUTATION WITH DOM-BASED  
ISOMORPHISM**

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See application file for complete search history.

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**G06F 17/30** (2006.01)  
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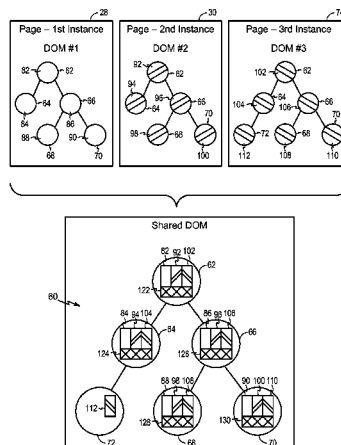
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(57) **ABSTRACT**

Methods and devices for accelerating webpage rendering by a browser store document object model (DOM) tree structures and computations of rendered pages, and compare portions of a DOM tree of pages being render to determining if portions of the DOM tree structures match. If a DOM tree of a webpage to be rendered matches a DOM tree stored in memory, the computations associated with the match DOM tree may be recalled from memory, obviating the need to perform the calculations to render the page. A tree isomorphism algorithm may be used to recognize DOM trees stored in memory that match the DOM tree of the webpage to be rendered. Reusing rendering computations may significantly reducing the time and resources required for rendering web pages. Identifying reusable portions of calculation results based on DOM tree isomorphism enables the browser to reuse stored webpage rendering calculations even when URLs do not match.

**44 Claims, 21 Drawing Sheets**



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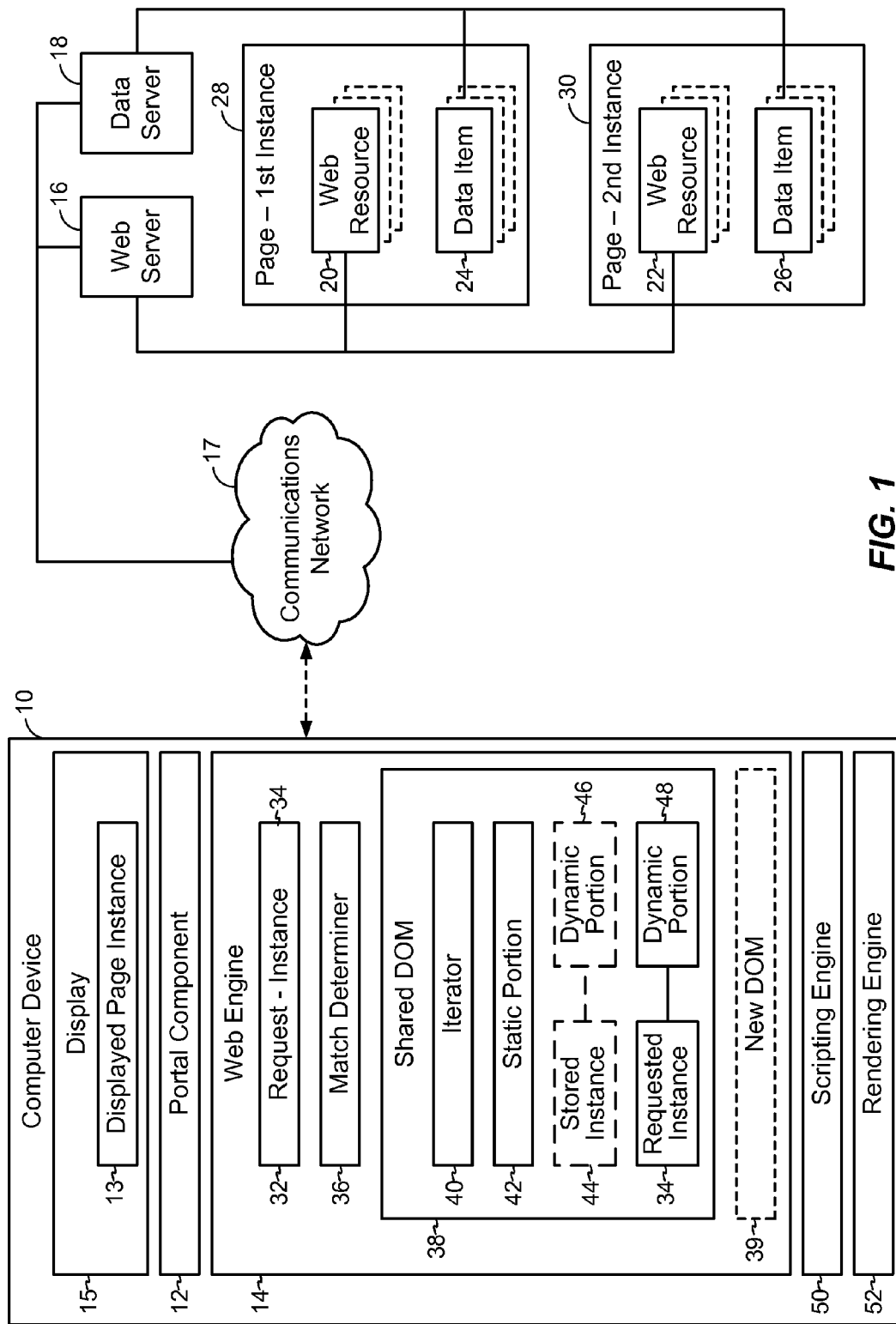


FIG. 1

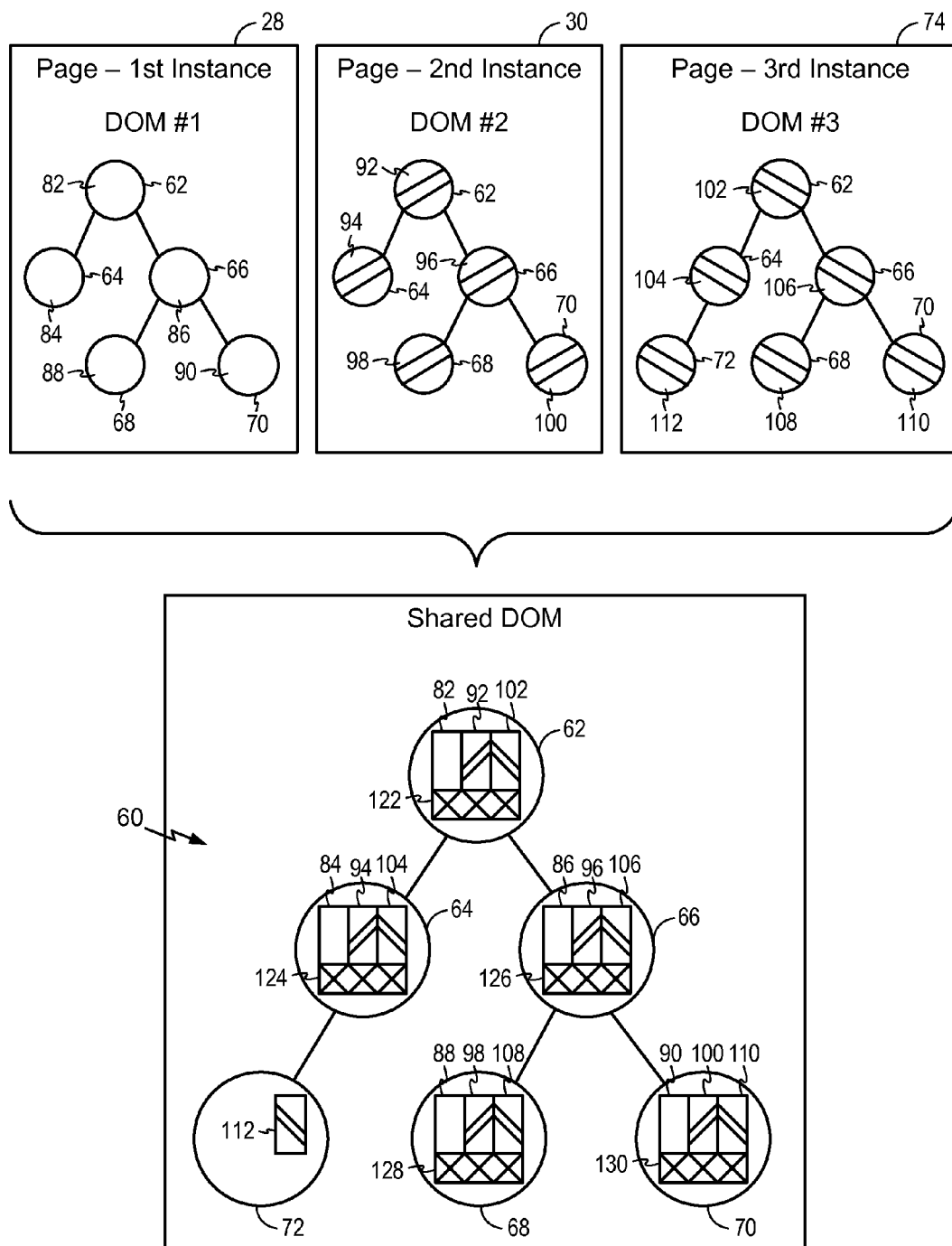
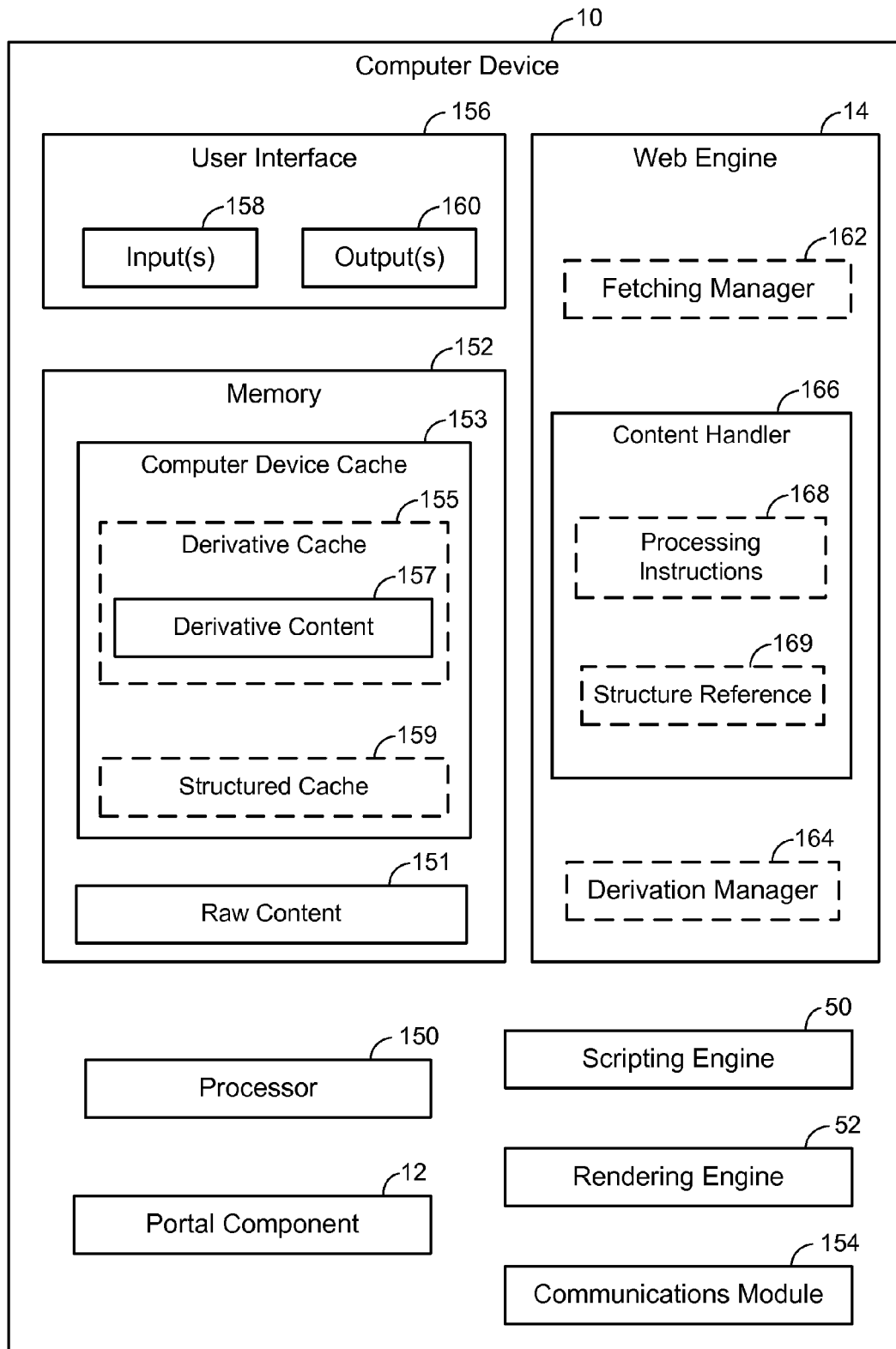
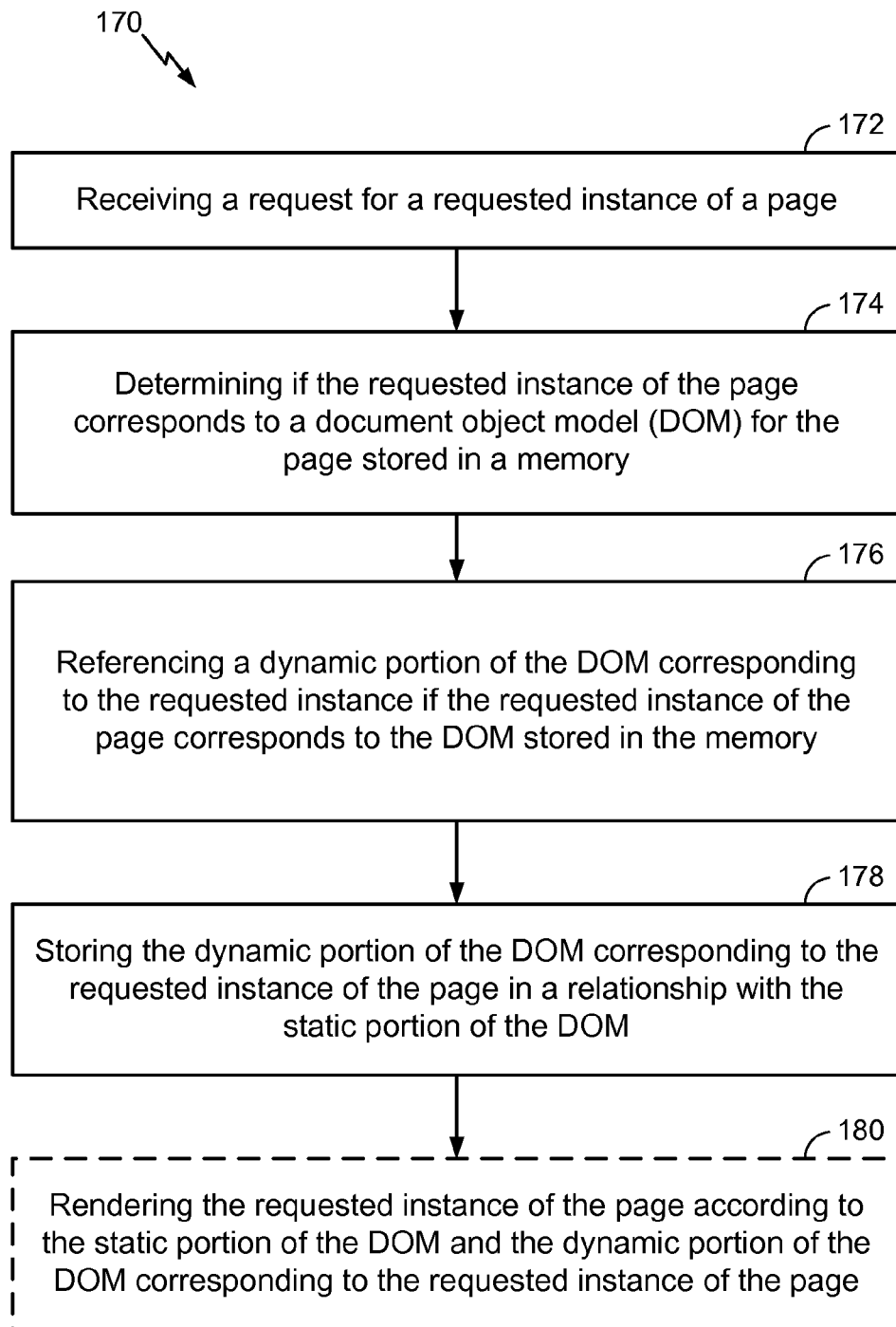


FIG. 2

**FIG. 3**

**FIG. 4**

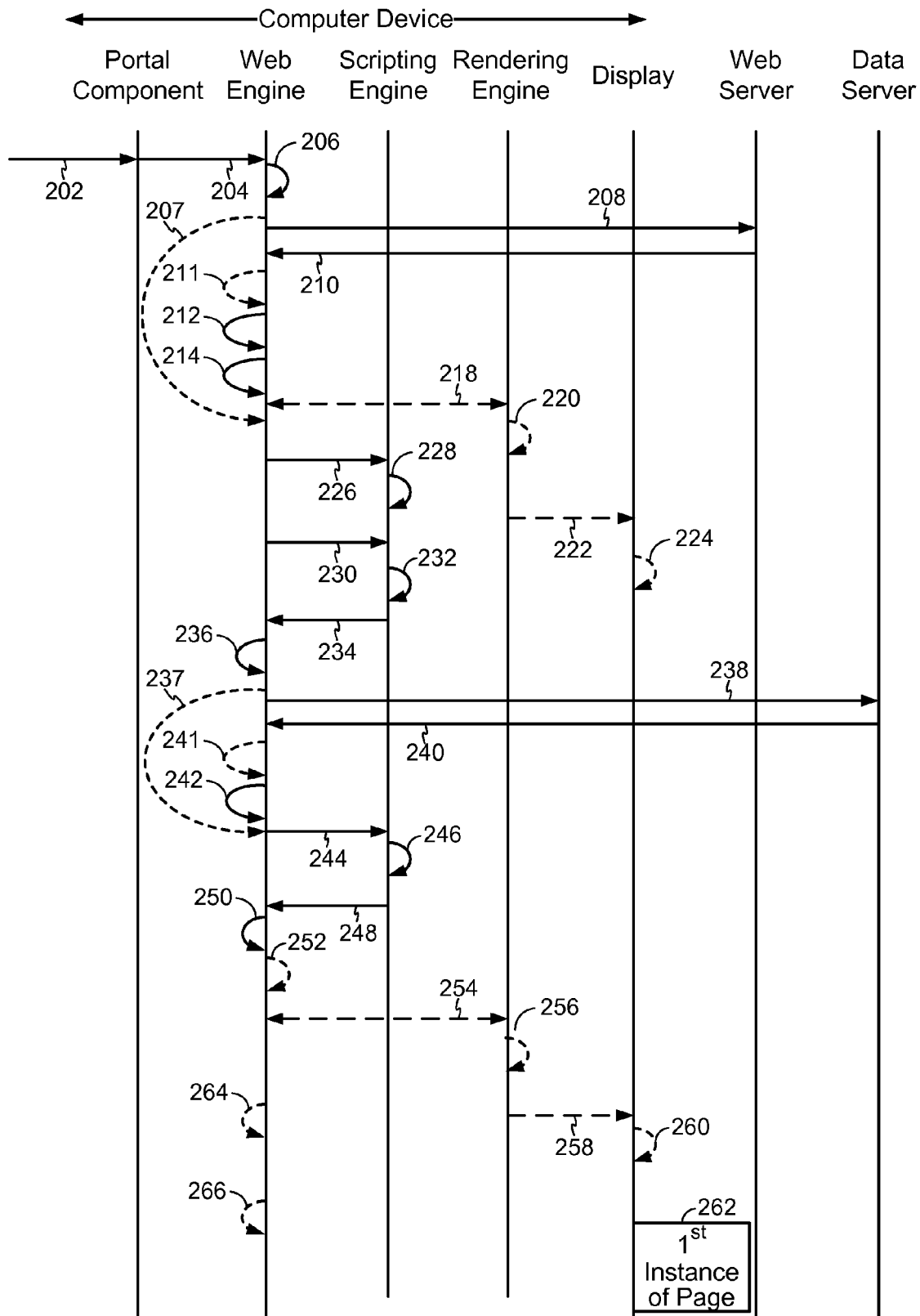


FIG. 5

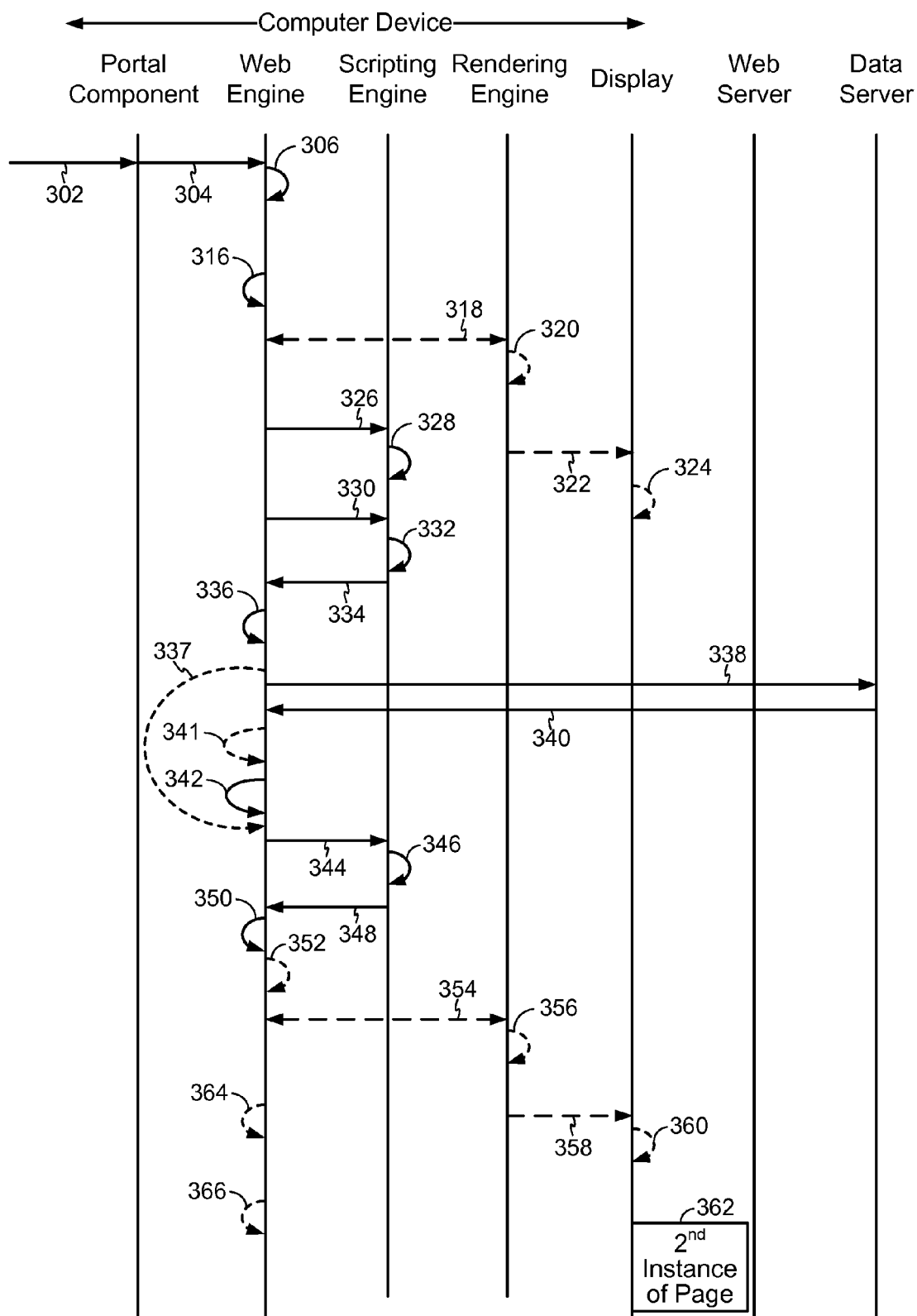
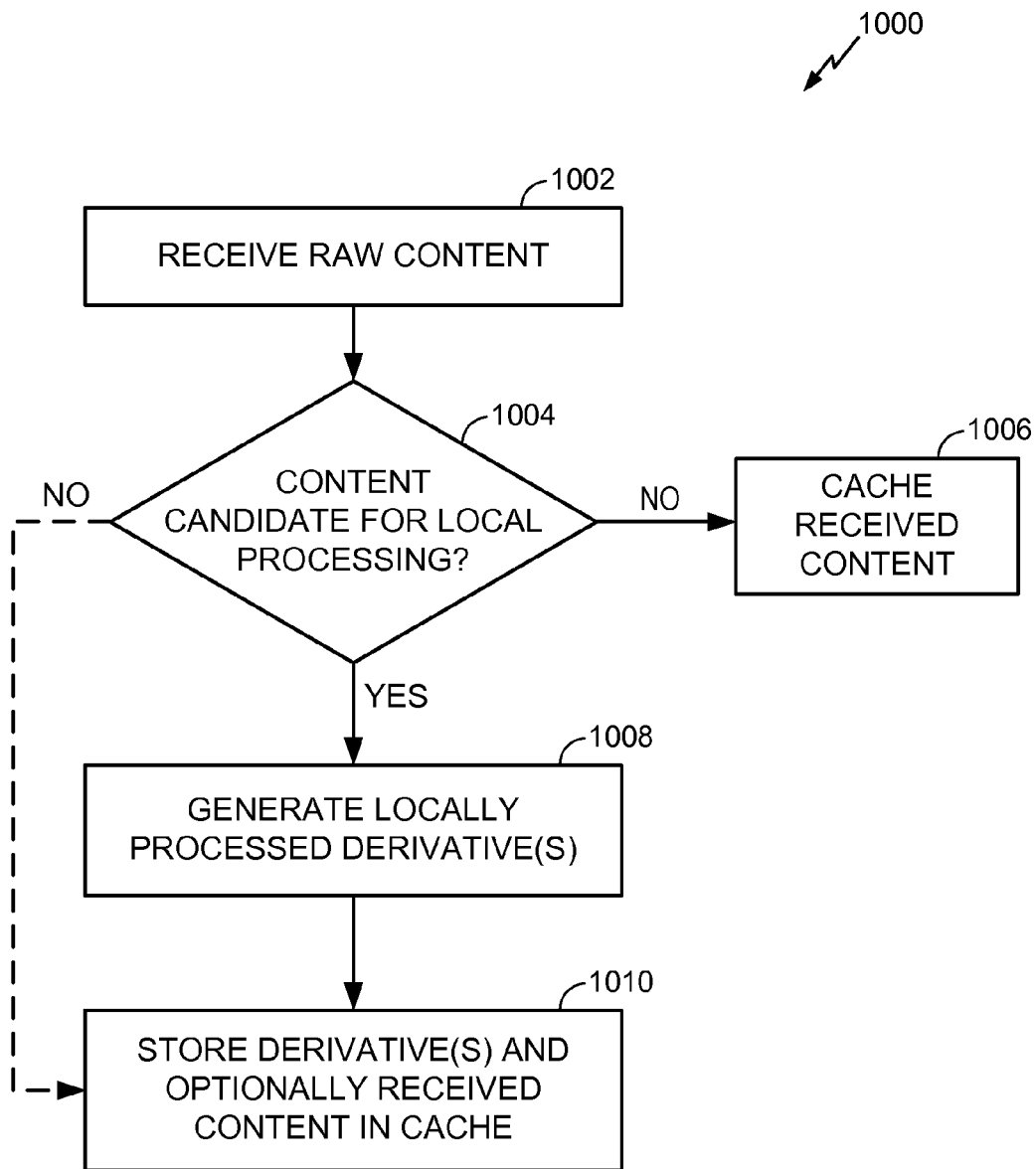
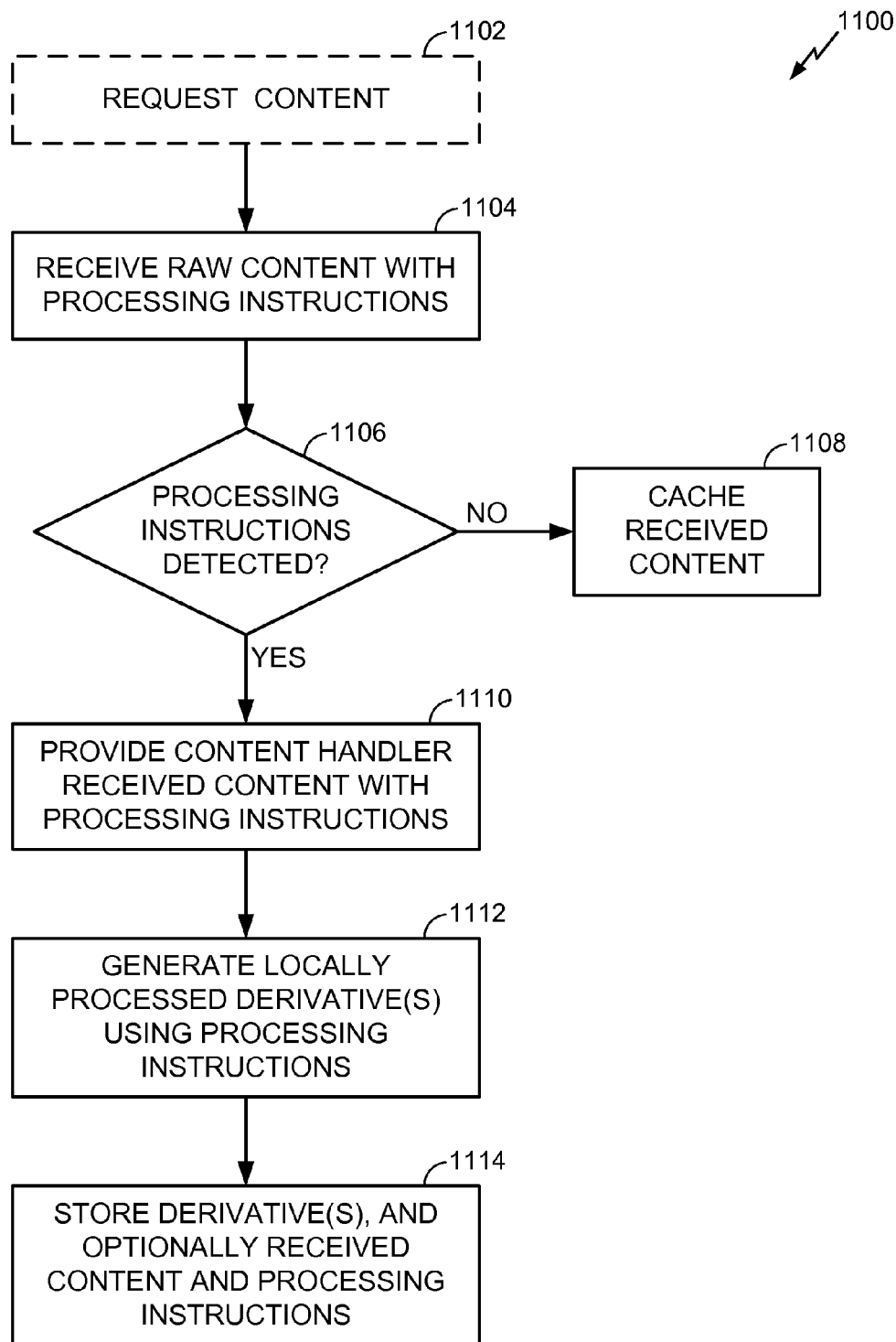
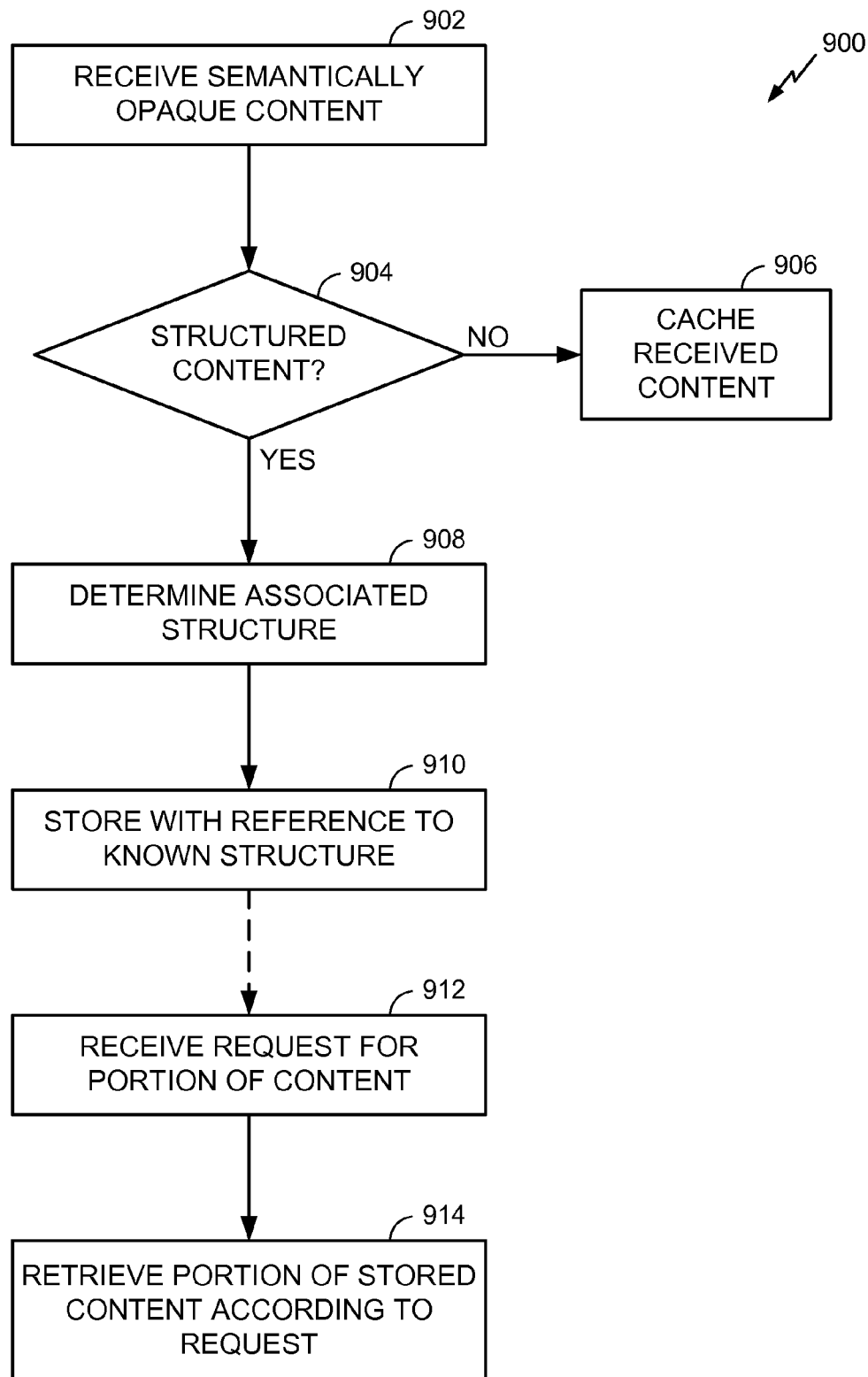


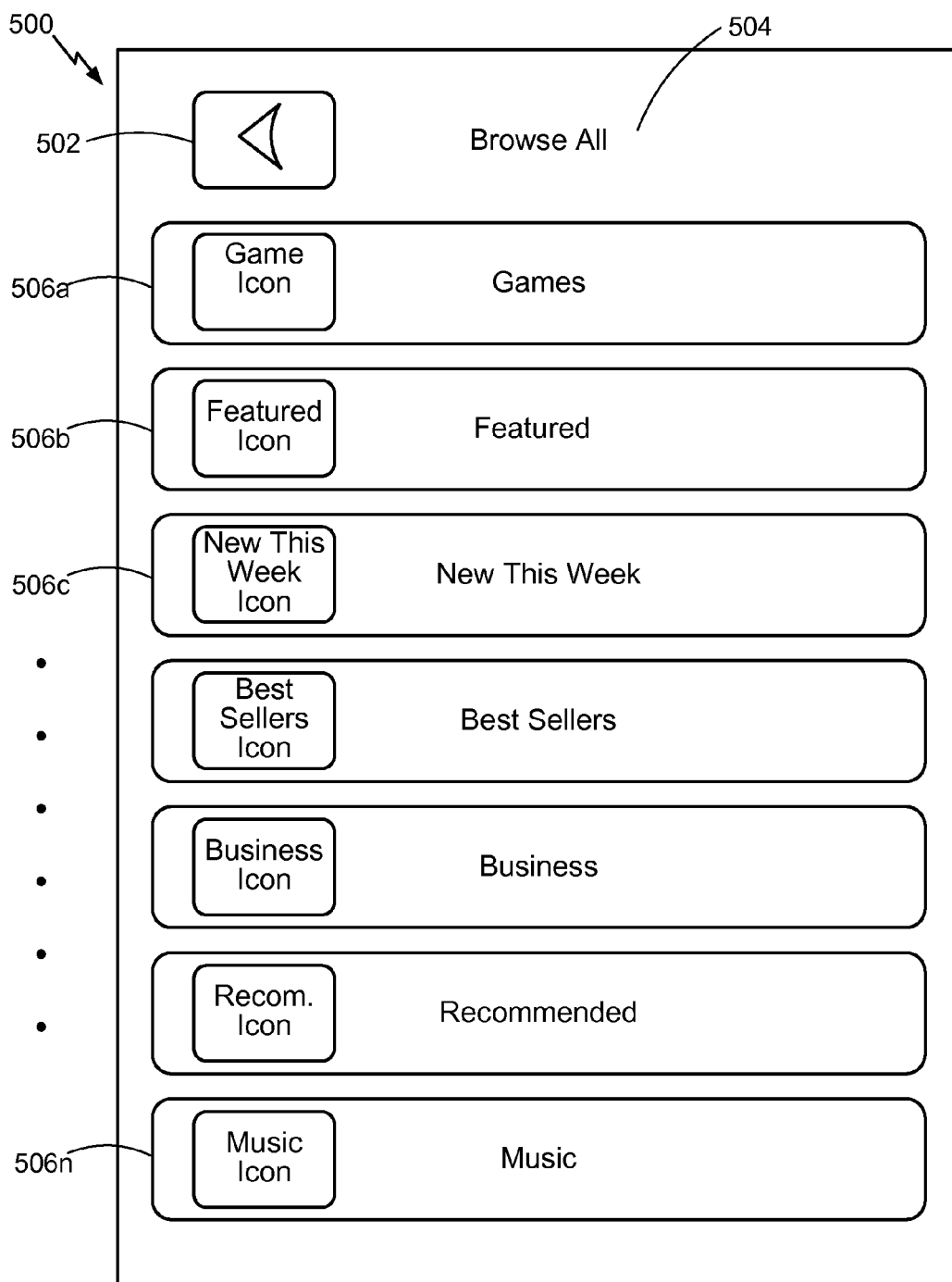
FIG. 6



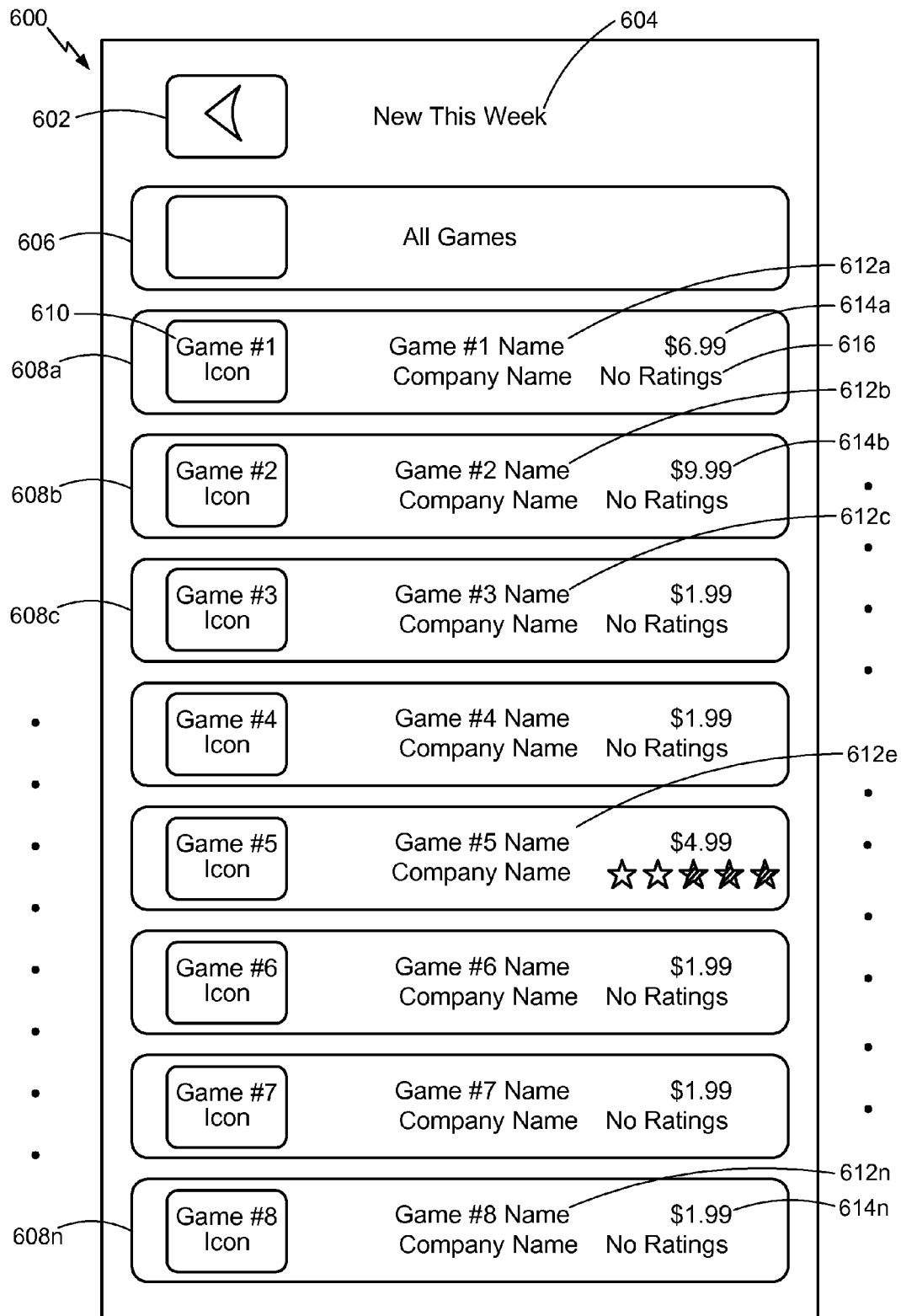
**FIG. 7**

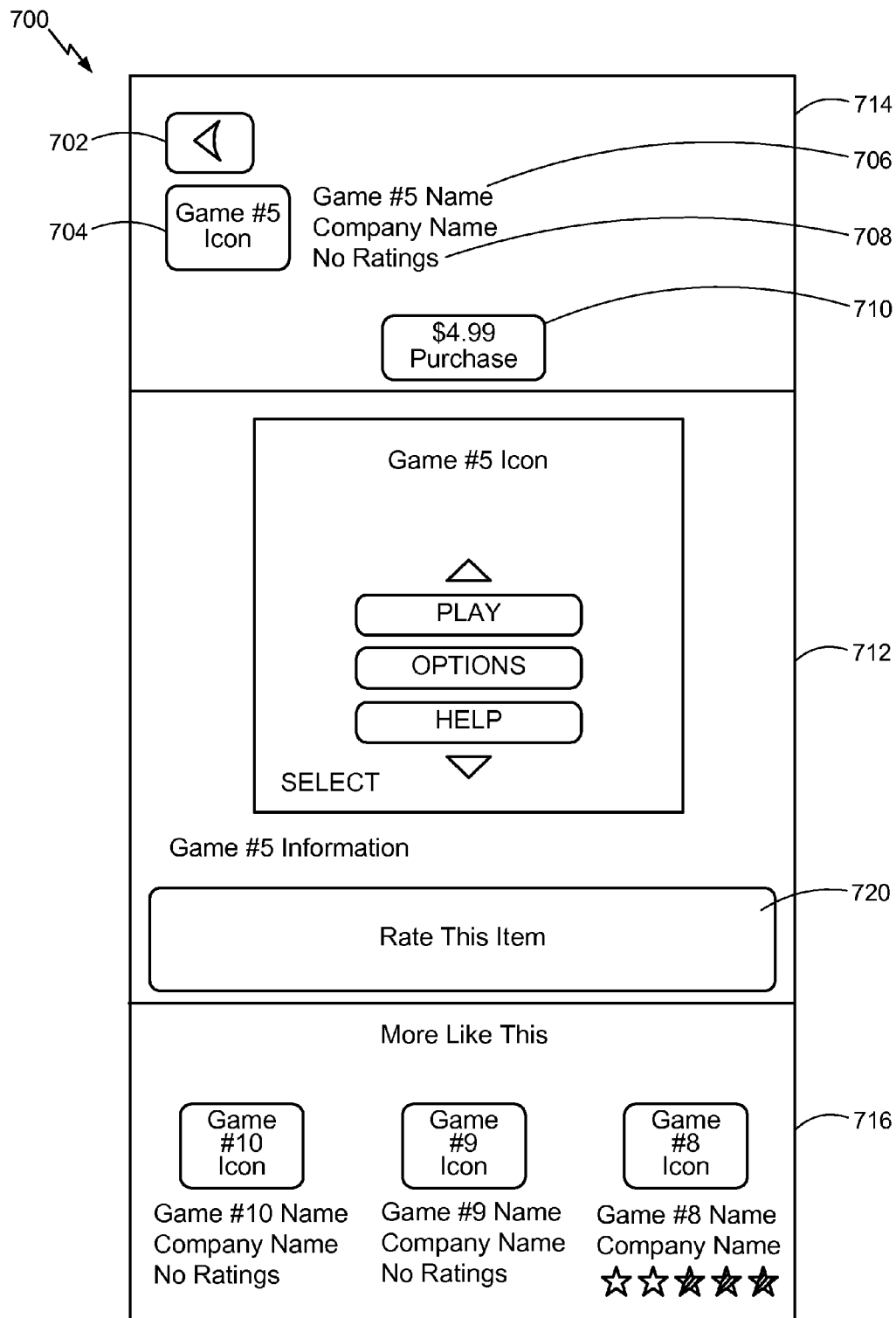
**FIG. 8**

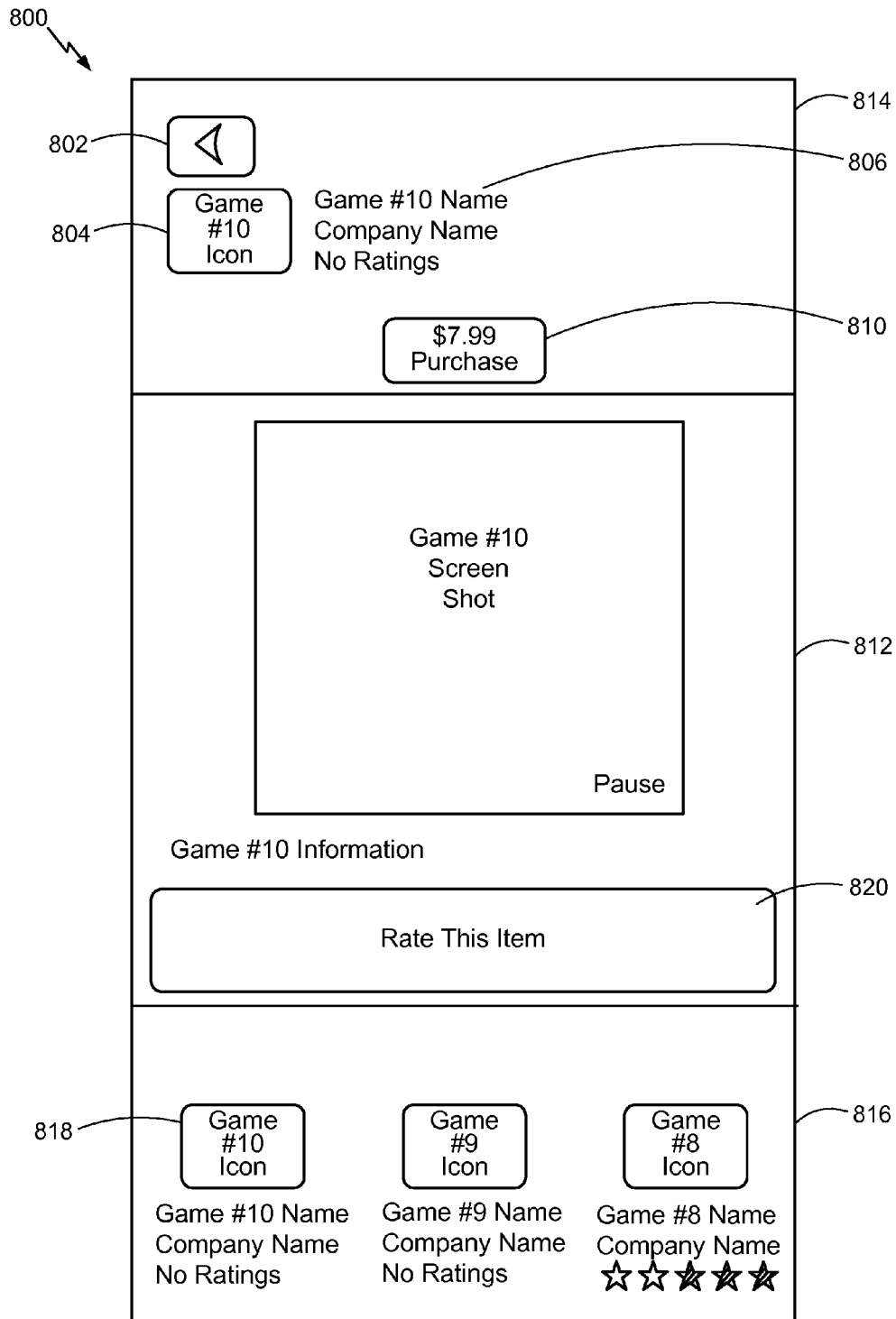
**FIG. 9**

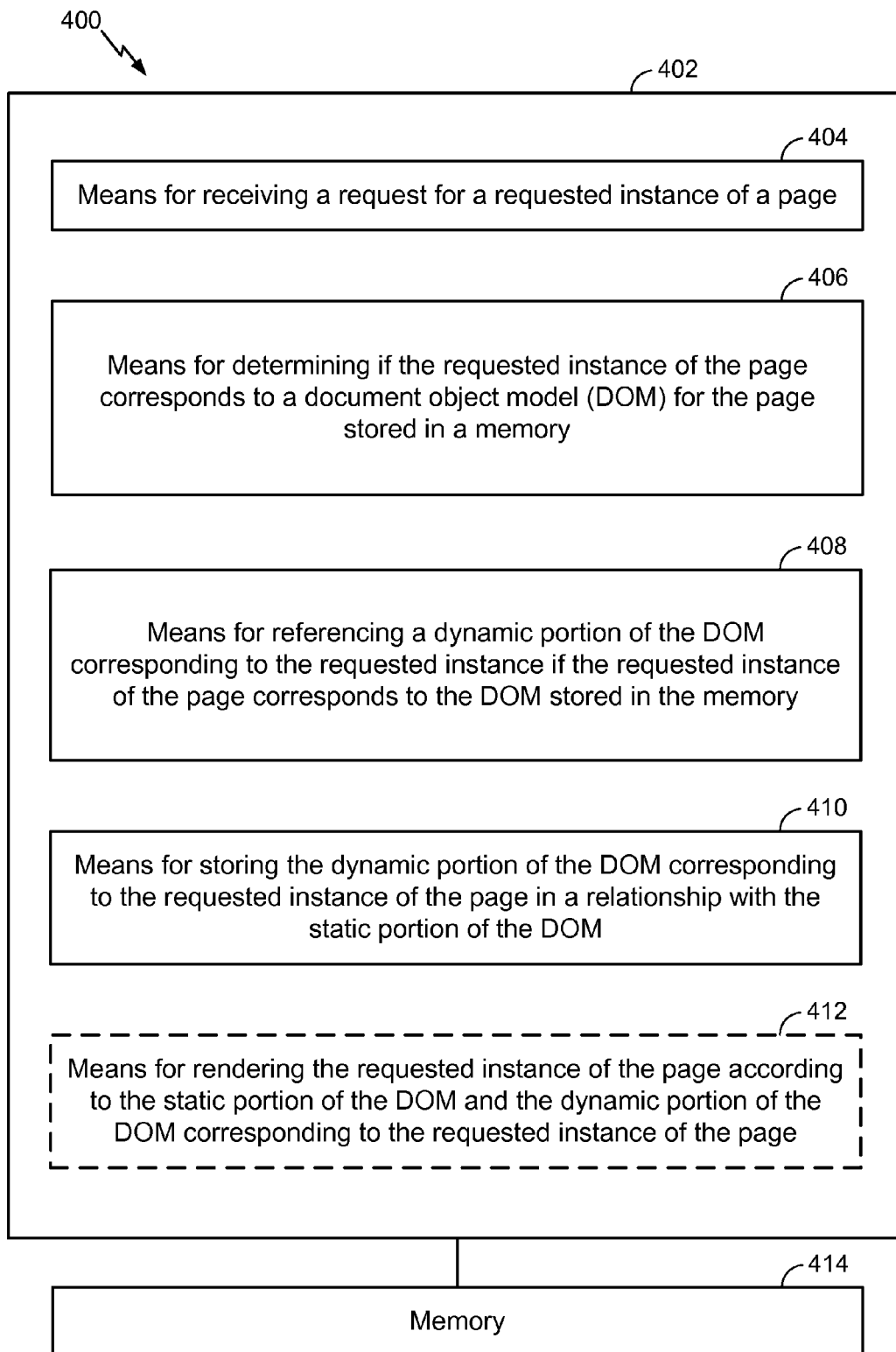


**FIG. 10**

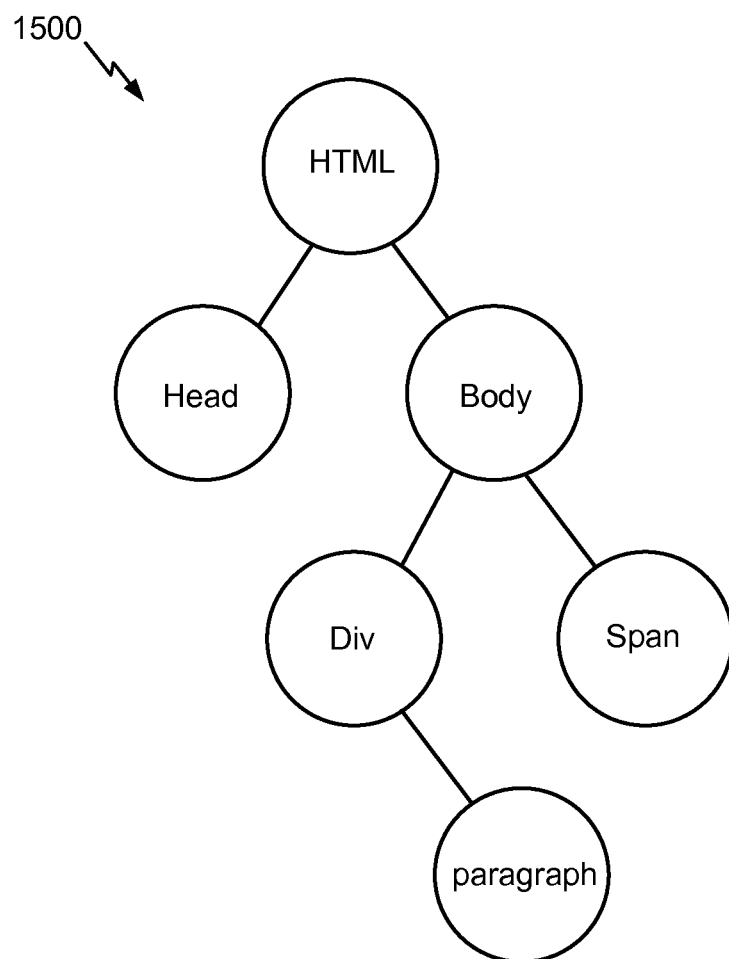
**FIG. 11**

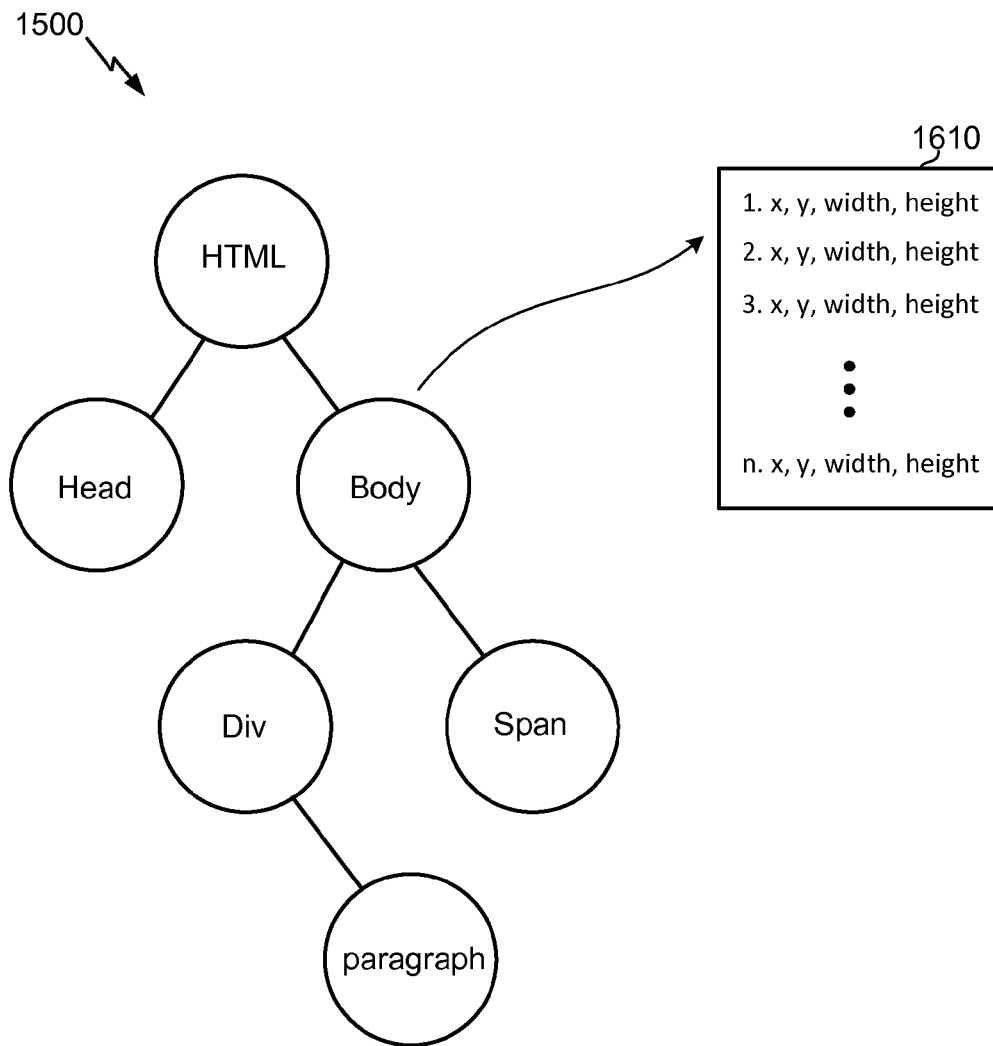
**FIG. 12**

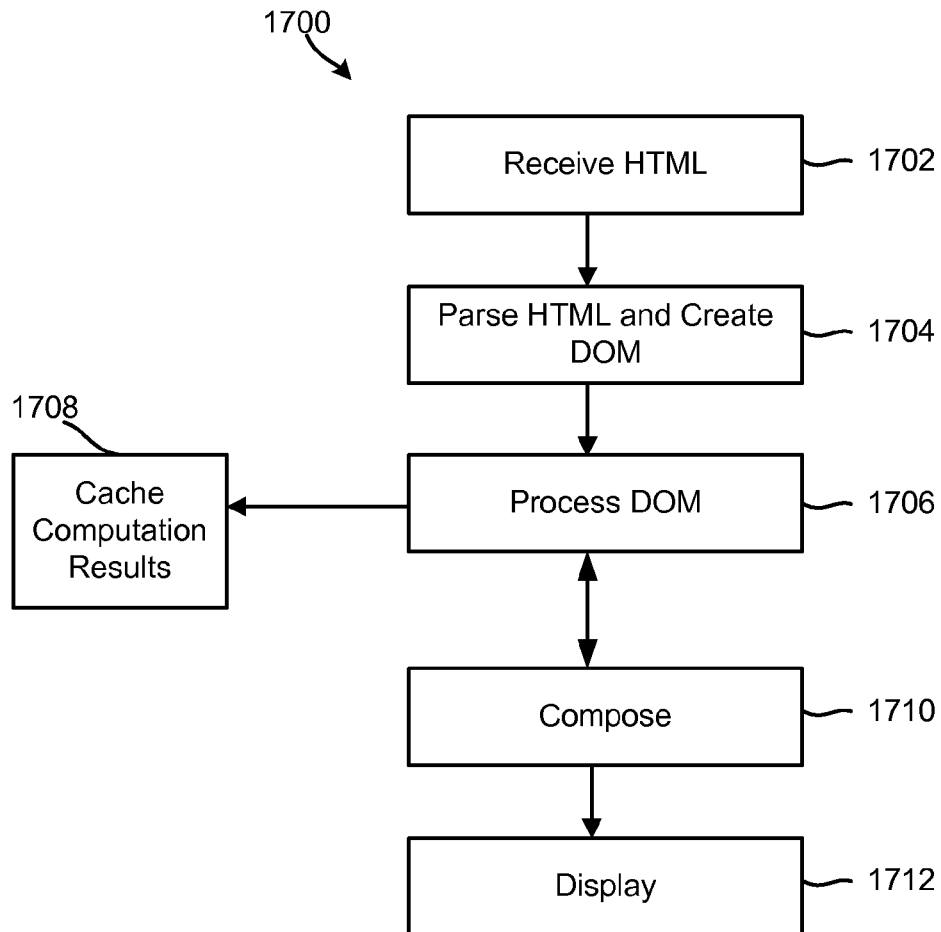
**FIG. 13**

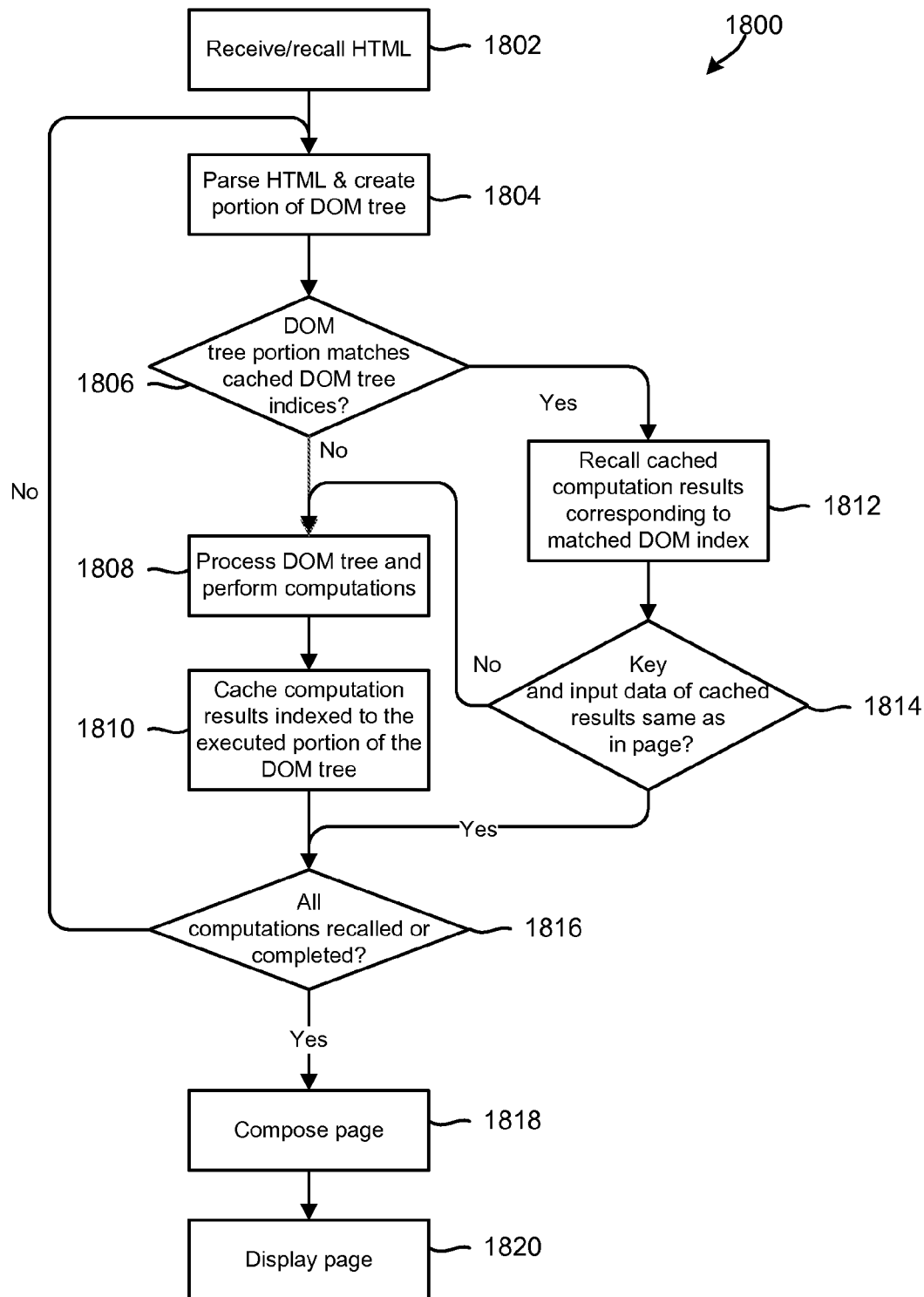
**FIG. 14**

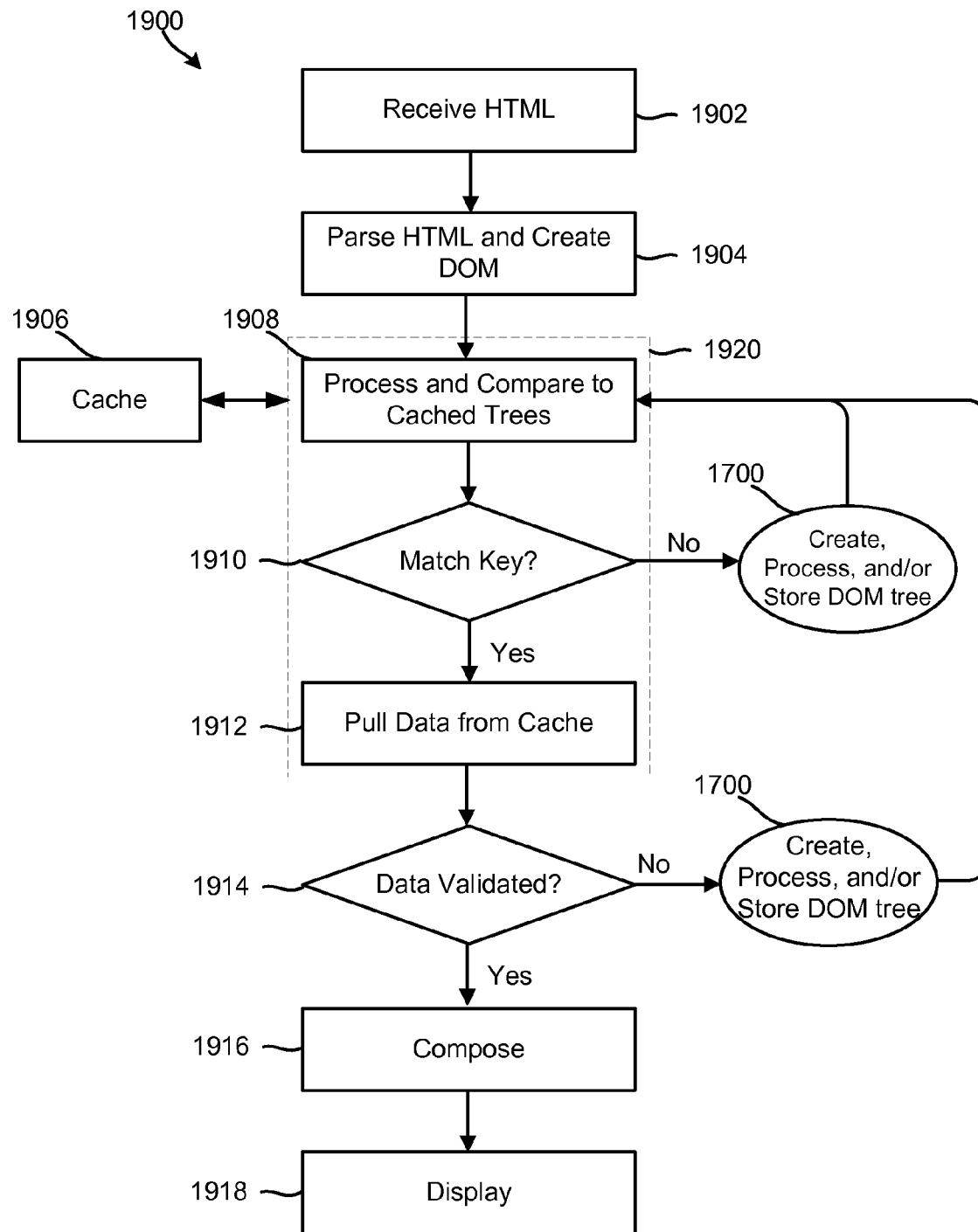


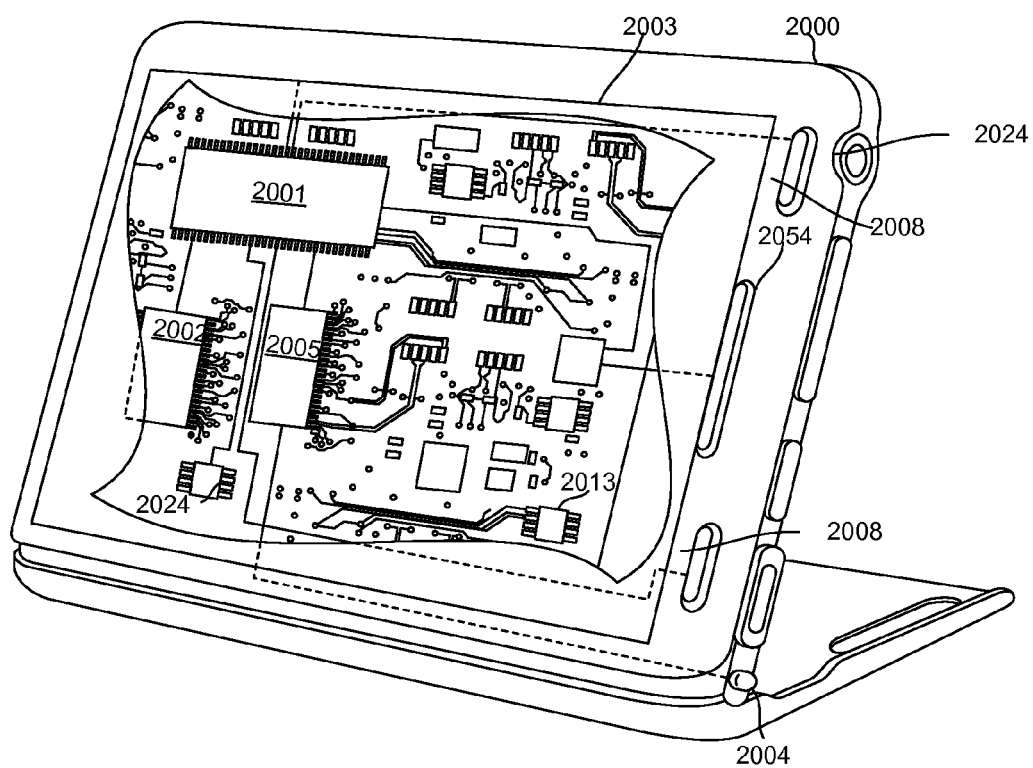
**FIG. 15**

**FIG. 16**

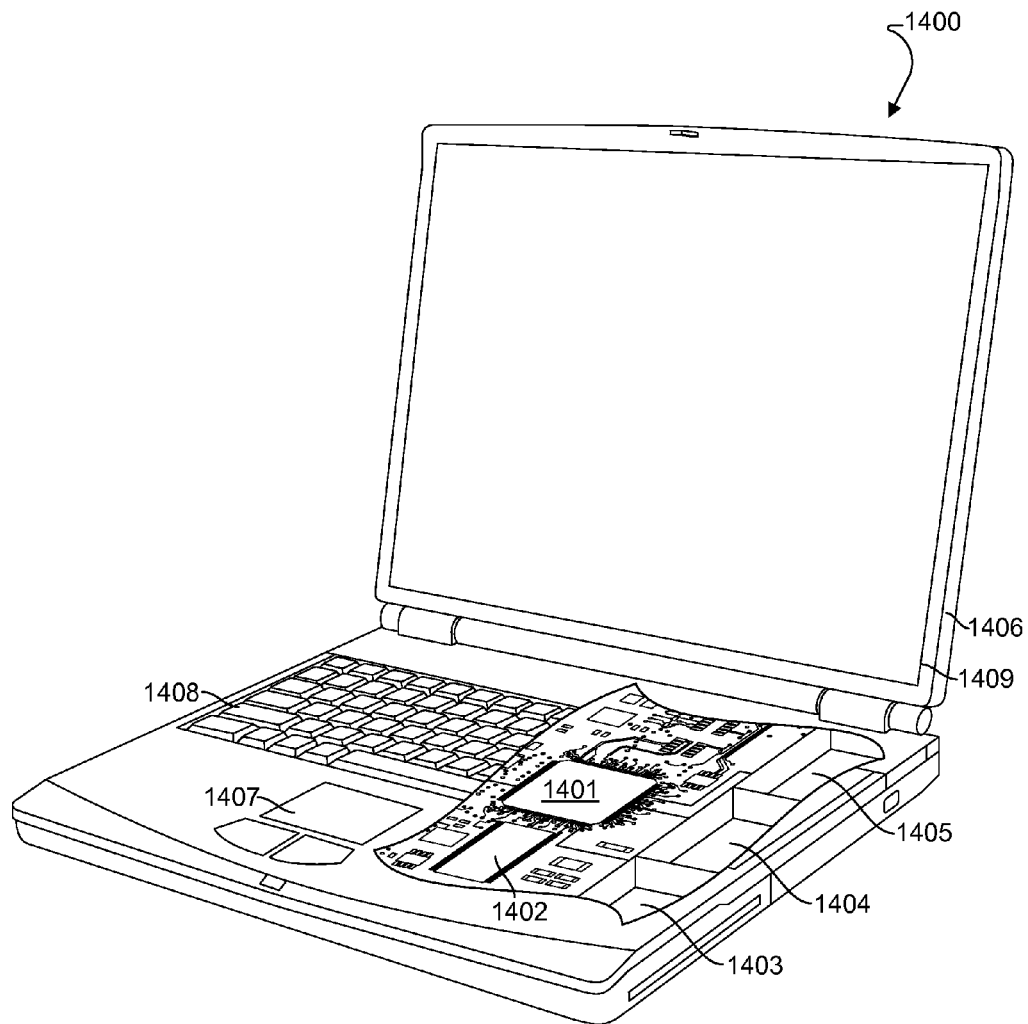
**FIG. 17**

**FIG. 18**

**FIG. 19**



**FIG. 20**

**FIG. 21**

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# MEMOIZING WEB-BROWSING COMPUTATION WITH DOM-BASED ISOMORPHISM

## RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 12/730,967, entitled "Apparatus and Methods for Rendering a Page" filed Mar. 24, 2010, which claims the benefit of priority to U.S. Provisional Application No. 61/248,909 entitled "Apparatus and Methods of Rendering a Page" filed Oct. 6, 2009, and U.S. Provisional Application No. 61/165,238 entitled "Method and Apparatus for Facilitating Efficient Local Caching" filed Mar. 31, 2009, all of which are assigned to the assignee hereof and are hereby incorporated by reference in their entirety.

## FIELD OF THE INVENTION

The following description relates generally to computing device communications, and more particularly to apparatus and methods of rendering a page.

## BACKGROUND

A rendering of a page, such as a web page, on a computing device is affected by a document object model (DOM) tree of the page. The DOM tree defines one or more nodes in child-parent relationships, including properties and/or attributes of the respective DOM node and its style attributes. When a page is launched, its .html files are read from a cache, parsed, a DOM tree is constructed, and then embedded or an external cascading style sheet (css) is applied. These operations are performed every time a page is loaded, which takes a significant amount of time, thereby leading to a less than satisfactory user experience.

Moreover, this amount of time is exacerbated in a resource-constrained environment, such as with a mobile computing device, e.g. a mobile phone, personal digital assistant (PDA) or other relatively small, portable devices having relatively limited processing capability, memory, and/or communications throughput when compared to a non-mobile computing device. Thus, the user experience suffers even more with a mobile computing device.

Therefore, improvements in rendering of a page are desired.

## SUMMARY

The following presents a simplified summary of one or more aspects in order to provide a basic understanding of such aspects. This summary is not an extensive overview of all contemplated aspects, and is intended to neither identify key or critical elements of all aspects nor delineate the scope of any or all aspects. Its sole purpose is to present some concepts of one or more aspects in a simplified form as a prelude to the more detailed description that is presented later.

One aspect relates to a method for rendering a page on a computer device. The method may include receiving, at a computer device, a request for a requested instance of a page. In addition, the method may include determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. Further, the method may also include retrieving a

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dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page. Moreover, the method may include storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM.

Another aspect relates to at least one processor configured to render a page on a computer device. The processor may include a first module for receiving, at a computer device, a request for a requested instance of a page. The processor may also include a second module for determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. In addition, the processor may include a third module for retrieving a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page. The processor may also include a fourth module for storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM.

Yet another aspect relates to a computer program product for rendering a page on a computer device. The computer program product may include a computer-readable medium including at least one instruction for causing a computer to receive, at a computer device, a request for a requested instance of a page. The computer-readable medium may also include at least one instruction for causing a computer to determine if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. The computer-readable medium may further include at least one instruction for causing a computer to retrieve a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page. Moreover, the computer-readable medium may also include at least one instruction for causing a computer to store the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM.

Another aspect relates to an apparatus. The apparatus may include means for receiving, at a computer device, a request for a requested instance of a page. In addition, the apparatus may include means for determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. The apparatus may also include means for retrieving a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page. The apparatus may further include means for storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM.



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Still another aspect relates to an apparatus for rendering a page on a computer device. The apparatus may include a portal component configured to receive a request for a requested instance of a page. The apparatus may also include a web component configured to determine if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. Additionally, the apparatus may include the web component configured to retrieve a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page. The apparatus may further include the web component configured to store the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM.

The described aspects relate to a method, apparatus or computer program product for rendering a page on a computer device, comprising actions, means for or instructions for receiving, at a computer device, a request for a requested instance of a page; determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory, wherein the DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page, retrieving a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory, wherein the dynamic portion is unique to the requested instance of the page, and storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM, and, optionally, for rendering the requested instance of the page according to the static portion of the DOM and the dynamic portion of the DOM corresponding to the requested instance of the page.

Other aspects relate to re-using computations of web-browsers by associating stored page rendering computations with DOM tree structure and identifying reusable calculations by recognizing a stored DOM tree pattern that matches at least a portion of a DOM tree of a page to be rendered. These aspects improve performance of a browser by enabling reuse HTML processing computations, in addition to the traditional caching of the HTML data, so they can be reused when rendering future pages even when the URL of page of saved computations is not the same as the current page to be rendered. In such aspects, The method for rendering a page on a computing device may include receiving, in a processor of the computing device, a request to display a web page, receiving HTML code corresponding to the requested web page, parsing the received HTML code to generate a document object model (DOM) tree, determining if a portion of generated DOM tree is isomorphic with one or more portions of a DOM tree stored in memory, retrieving from memory previously stored calculations associated with isomorphic portions of the DOM trees when it is determined that a portion of generated DOM tree is isomorphic with one or more portions of a DOM tree stored in memory, composing the requested webpage using the retrieved calculations, and displaying the requested web page on an electronic display of the computing device. In such a method, determining if a portion of generated DOM tree is isomorphic with one or more portions of a DOM tree stored in memory may include comparing the generated DOM tree with DOM tree structures stored in

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memory using a tree isomorphism comparison algorithm, determining if the portion of the generated DOM tree has a structure that is identical to one or more portions of DOM trees stored in memory, or determining if the portion of the generated DOM tree is structurally similar to one or more portions of the DOM tree stored in the memory. In an aspect, retrieving from memory previously stored calculations associated with isomorphic portions of the DOM trees may include accessing a cache mechanism that stores the computation results of the portions of the DOM trees such that they are indexed by a computed hash value based on a DOM sub-tree structure corresponding to portions of the DOM trees.

In an aspect, the method may further include determining whether key values and input values used to create computation results of a DOM tree in memory equal key values and input values of the generated DOM tree, in which case retrieving from memory previously stored calculations associated with isomorphic portions of the DOM trees may be performed only when it is determined that the key values and input values used to create computation results of a DOM tree in memory equal key values and input values of the generated DOM tree. Also, the method may further include completing HTML code computations for the generated DOM tree when it is determined that the generated DOM tree is not isomorphic with any of the one or more portions of the DOM tree stored in memory, and storing the results of the HTML computations indexed with the generated DOM tree in memory. In such an aspect, storing the generated DOM tree may include storing at least a portion of the generated DOM tree in a key-value data structure in which DOM tree elements are stored in association with corresponding HTML computation results, in which case the structured cache may be implemented using a hash-map data structure, and the key-value data structure may include a hash-map data structure. In such an aspect, retrieving previously stored calculations from the memory may include evaluating hash-keys associated with nodes of the stored DOM tree that are isomorphic with the portion of the generated DOM tree.

Other aspects relate to computing devices comprising a processor configured with processor-executable instructions to perform operations of the foregoing methods. Further aspects relate to computing devices comprising means for accomplishing the functions of the foregoing methods. Still further aspects relate to non-transitory computer readable storage media having stored thereon processor-executable instructions configured to cause a processor of a computing device to perform operations of the foregoing methods.

To the accomplishment of the foregoing and related ends, the one or more aspects comprise the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative features of the one or more aspects. These features are indicative, however, of but a few of the various ways in which the principles of various aspects may be employed, and this description is intended to include all such aspects and their equivalents.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate exemplary aspects of the invention. Together with the general description given above and the detailed description given below, the drawings serve to explain features of the invention not to limit the disclosed aspects.

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FIG. 1 is a schematic diagram of an aspect of a system for rendering a page.

FIG. 2 is a schematic diagram of an aspect of a shared DOM.

FIG. 3 is a schematic diagram of an aspect of a computer device of FIG. 1.

FIG. 4 is a flowchart of an aspect of a method of rendering a page.

FIG. 5 is a flowchart of an aspect of rendering a first instance of a page.

FIG. 6 is a flowchart of an aspect of rendering a second instance of a page.

FIG. 7 is an exemplary method for facilitating efficient local caching according to an aspect.

FIG. 8 is an exemplary method for facilitating content modification through processing instructions before storage in cache, according to one aspect.

FIG. 9 is an exemplary method for facilitating structured storage in cache, according to one aspect.

FIG. 10 is a schematic diagram of an example main page in accordance with an aspect.

FIG. 11 is a schematic diagram of an example catalog page in accordance with an aspect.

FIG. 12 is a schematic diagram of an example of an item detail page in accordance with an aspect.

FIG. 13 is a schematic diagram of another example of an item detail page in accordance with an aspect.

FIG. 14 is a schematic diagram of an aspect of an apparatus for rendering a page.

FIG. 15 is a schematic diagram of a sample DOM tree generated by a browser parsing HTML code for a requested webpage.

FIG. 16 is a schematic diagram of a sample DOM tree having calculated values stored for each node.

FIG. 17 is a flowchart of an aspect method for creating, processing, and storing the DOM tree on a first execution of a browser and/or first occurrence of a web page having an unidentified DOM structure.

FIG. 18 is a flowchart of an aspect method for creating, processing, storing, and/or retrieving portions of a DOM tree on subsequent executions of the browser.

FIG. 19 is a flowchart of another aspect method for creating, processing, storing, and/or retrieving portions of a DOM tree on subsequent executions of the browser.

FIG. 20 is a component block diagram of an example receiver device suitable for use with the various embodiments.

FIG. 21 is a component block diagram of an example server suitable for use with various embodiments.

## DETAILED DESCRIPTION

Various aspects are now described with reference to the drawings. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of one or more aspects. It may be evident; however, that such aspect(s) may be practiced without these specific details.

The described aspects relate to fetching and rendering a page, such as a web page having web resources and data items. In addition, the described aspects provide a virtual effect of transitioning between web pages, e.g., providing links for a user to move forward and backward between web pages. The web page is rendered according to a corresponding document object model (DOM), which defines the components, relative structure, and behavior of the respective components that define the page. Different instances of the

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same page may share some common portions of the DOM, while having other unique portions that differentiate one instance over the next instance of the page.

According to one or more aspects, apparatus, and methods of rendering a page provide a web engine or other components operable to create a shared DOM that may be used by two or more instances of the page. The shared DOM includes a static DOM portion that is common to the different instances of a page, and one or more dynamic DOM portions that are unique to a respective one or more instances of the page. As such, the described aspects improve efficiency in page rendering by reusing the static DOM portion in rendering a new instance of a page that corresponds to a stored or cached DOM, which can be based on a previously processed, different instance of the same page, thereby avoiding having to create an entirely new DOM for each instance of the page.

For example, these aspects may be described with reference to a use case such as a mobile shopping application executed by a mobile phone. It should be understood, however, that this example use case is for illustration only, and that many other use cases exist. In the mobile shopping application example, web pages corresponding to the mobile shopping application may include a tree or hierarchy of different types of pages, such as a main page having a catalog listing, one or more catalog pages having item listings and/or other catalog listings, and one or more item detail pages, which may also link to other item detail pages, and/or additional detail pages such as pricing or purchasing pages. Different instances of the same page, such as an item detail page for a first game and an item detail page for a second game, may share similar structure and possibly some similar data, but they may also each have unique data, such as a name of each respective game. As such, typically, each item detail page has a different, corresponding DOM. In the present aspects, however, the item detail pages instead have a shared DOM that includes a static DOM portion corresponding to common DOM elements between the different instances of the page, and one or more dynamic DOM portions that associate the unique data items with the respective instance of the page. For example, in this case, the static DOM portion may comprise a same layout of the first game item detail page and the second game item detail page, while the dynamic data items, such as the first game name and the second game name, are represented by a dynamic DOM portion.

In other words, in one aspect, when a unique instance of a page (for example, an “itemdetail” page) has never been fetched or cached on a computer device, and that instance of the page is requested, the described aspects provide a behavior that results in fetching the page data (for example, including the hyper text markup language (html) or extensible html (xhtml), cascading sheet style (css), and javascript as)) and creating a static portion of a document object model (DOM) from the xhtml and css. This static portion of the DOM is stored in cache and can be reused. For that page, the js is then executed, resulting in one or more data requests (for example, an XMLHttpRequest (XHR)). The initial js and the handling of each of the one or more responses results in the creating of one or more dynamic portions of the DOM for that instance of the page. Then, when a second instance of the page is requested, the static DOM portion can be reused, and the js is executed for the new query string of the request corresponding to the second instance of the page, resulting in one or more new data requests and the creating of one or more dynamic portions of the DOM for the new instance of the page. As a result, the shared DOM includes at least one static portion and

one or more dynamic portions, enabling the DOM to define a shared DOM for use in rendering different instances of the page.

Accordingly, in an aspect, reuse of the initial or static state or portions of the DOM reduces page transitioning time. In one or more aspects, state or DOM portion reuse may be achieved by maintaining separate, or alternatively integrated, data structures corresponding to the static and dynamic states or portions of the DOM.

Further, in one or more aspects, one or more advantages may include: no or low memory overhead, as only a table of properties are copied; fast loading of the page, as only one time parsing of HTML and applying of CSS rules occurs; cleaner and less complex code as compared to other implementations, as different DOMs do not need to be created for different instances of the same page; no extra walk through the DOM tree, as the rendering can focus on updating the dynamic DOM portions considering the static DOM portions do not change; and dynamic properties are created on demand on a page load and are removed on an existing walk through the DOM on navigating back to an instance of the page.

Optionally, in some aspects, the DOM and corresponding page content may be cached, and the cache may include a derivative cache or a structured cache. The derivative cache may store content derived from received content. For example, in one aspect, upon receipt of raw content, such as but not limited to xhtml, cascading sheet styles or javascript, the computer device may further process the raw content to generate derivative content. For instance, in an aspect, it should be appreciated that the derivative content may include the static portion of the DOM, e.g., the static portion of the DOM may be created and/or derived from the received xhtml and css. It may be determined to store the derivative content, for example, in the derivative cache, as the resources expended to generate derivative content are relatively expensive. In one aspect, this caching of derivative content may assist in efficiently facilitating subsequent usage of the cached content through the use of this pre-prepared, derivative content, such as if the content is used frequently.

Another example of derivative content may include the computer device fetching a program to be run when it is retrieved from cache. Rather than compiling the fetched program every time computer device retrieves the program from the cache, the computer device may compile the program. The compiled program, or derivative content, may be stored in the derivative cache, ready for subsequent use. Additionally, the derivative content may be associated with the received source.

In another aspect, computer device cache may further include a structured cache. The structured cache allows for storage of content in a manner such that retrieving programs or the like may selectively choose useful portions of the cached content for retrieval. For example, without the present apparatus and methods, the cached content may appear as semantically opaque content, thereby prohibiting selective retrieval of portions of the cached content. In one aspect, the structured cache can be organized in such a way as to allow selected known portions of a content item stored in the structured cache to be retrieved without requiring retrieval of the entire content item.

For example, assume content with a well known structure, such as java script object notation (JSON) content, is stored in the structured cache. Further assume a program or the like may only use a small portion of the JSON content, such as content associated with the manufacturer, the title, or the like. The structured cache allows for the selective removal of only

the portion of the content useful to the program, thereby reducing any intermediary processing that may have been required.

In another example, a content provider may introduce origin-server generated entry points with content transmitted to the computer device. As such, when content with origin-server generated entry points is stored in a structured cache, subsequent removal of portions defined by the entry points may be facilitated.

Optionally, in some aspects, the described apparatus and methods may further include pre-fetching operations that can be performed to fetch and process a page prior to receipt of a request for that page.

Optionally, in some aspects, the described apparatus and methods may further include pre-derivation operations that can be performed to parse a web page into a DOM and cache the corresponding DOM prior to receipt of a request for that page.

Optionally, in some aspects, the described apparatus and methods may further include both the pre-fetching and the pre-derivation operations.

The pre-fetching operation and/or the pre-derivation operation can further increase the speed in rendering an instance of a page, thereby improving a user experience when transitioning from one page to another page.

In a further aspect, methods and devices for accelerating webpage rendering by a browser store document object model (DOM) tree structures and computations of rendered pages, and compare portions of a DOM tree of pages being render to determining if portions of the DOM tree structures match. If a DOM tree of a webpage to be rendered matches a DOM tree stored in memory, the computations associated with the match DOM tree may be recalled from memory, obviating the need to perform the calculations to render the page. A tree isomorphism algorithm may be used to recognize DOM trees stored in memory that match the DOM tree of the webpage to be rendered. As discussed above, reusing rendering computations may significantly reducing the time and resources required for rendering web pages. Identifying reusable portions of calculation results based on DOM tree isomorphism enables the browser to reuse stored webpage rendering calculations even when URLs do not match, thereby increasing the amount of rendering computations that can be reused by the browser.

Thus, the present aspects can efficiently render different instances of a page by reusing a static portion of the DOM, thereby saving processing or communication resources, or both.

As used in this application, the terms “component,” “module,” “system” and the like are intended to include a computer-related entity, such as but not limited to hardware, firmware, a combination of hardware and software, software, or software in execution. For example, a component may be, but is not limited to being, a process running on a processor, a processor, an object, an executable, a thread of execution, a program, and/or a computer. By way of illustration, both an application running on a computing device and the computing device can be a component. One or more components can reside within a process and/or thread of execution and a component may be localized on one computer and/or distributed between two or more computers. In addition, these components can execute from various computer readable media having various data structures stored thereon. The components may communicate by way of local and/or remote processes such as in accordance with a signal having one or more data packets, such as data from one component interacting

with another component in a local system, distributed system, and/or across a network such as the Internet with other systems by way of the signal.

Furthermore, various aspects are described herein in connection with a terminal, which can be a wired terminal or a wireless terminal. A terminal can also be called a system, device, subscriber unit, subscriber station, mobile station, mobile, mobile device, remote station, remote terminal, access terminal, user terminal, terminal, communication device, user agent, user device, or user equipment (UE). A wireless terminal may be a cellular telephone, a satellite phone, a cordless telephone, a Session Initiation Protocol (SIP) phone, a wireless local loop (WLL) station, a personal digital assistant (PDA), a handheld device having wireless connection capability, a computing device, or other processing devices connected to a wireless modem. Moreover, various aspects are described herein in connection with a base station. A base station may be utilized for communicating with wireless terminal(s) and may also be referred to as an access point, a Node B, or some other terminology.

In addition, the word “exemplary” is used herein to mean serving as an example, instance, or illustration. Any aspect or design described herein as “exemplary” is not necessarily to be construed as preferred or advantageous over other aspects or designs. Rather, use of the word exemplary is intended to present concepts in a concrete fashion. Moreover, the term “or” is intended to mean an inclusive “or” rather than an exclusive “or.” That is, unless specified otherwise, or clear from the context, the phrase “X employs A or B” is intended to mean any of the natural inclusive permutations. That is, the phrase “X employs A or B” is satisfied by any of the following instances: X employs A; X employs B; or X employs both A and B. In addition, the articles “a” and “an” as used in this application and the appended claims should generally be construed to mean “one or more” unless specified otherwise or clear from the context to be directed to a singular form.

The techniques described herein may be used for various wireless communication systems such as CDMA, TDMA, FDMA, OFDMA, SC-FDMA, and other systems. The terms “system” and “network” are often used interchangeably. A CDMA system may implement a radio technology such as Universal Terrestrial Radio Access (UTRA), cdma2000, etc. UTRA includes Wideband-CDMA (W-CDMA) and other variants of CDMA. Further, cdma2000 covers IS-2000, IS-95, and IS-856 standards. A TDMA system may implement a radio technology such as Global System for Mobile Communications (GSM). An OFDMA system may implement a radio technology such as Evolved UTRA (E-UTRA), Ultra Mobile Broadband (UMB), IEEE 802.11 (Wi-Fi), IEEE 802.16 (WiMAX), IEEE 802.20, Flash-OFDM, etc. UTRA and E-UTRA are part of Universal Mobile Telecommunication System (UMTS). 3GPP Long Term Evolution (LTE) is a release of UMTS that uses E-UTRA, which employs OFDMA on the downlink and SC-FDMA on the uplink. UTRA, E-UTRA, UMTS, LTE, and GSM are described in documents from an organization named “3rd Generation Partnership Project” (3GPP). Additionally, cdma2000 and UMB are described in documents from an organization named “3rd Generation Partnership Project 2” (3GPP2). Further, such wireless communication systems may additionally include peer-to-peer (e.g., mobile-to-mobile) ad hoc network systems often using unpaired unlicensed spectrums, 802.xx wireless LAN, BLUETOOTH and any other short- or long-range, wireless communication techniques.

Various aspects or features will be presented in terms of systems that may include a number of devices, components, modules, and the like. It is to be understood and appreciated

that the various systems may include additional devices, components, modules, etc. and/or may not include all of the devices, components, modules etc. discussed in connection with the figures. A combination of these approaches may also be used.

Referring to FIG. 1, in one aspect, apparatus and methods for rendering a page, such as a web page, include a computer device 10 having a portal component 12 that interacts with a web engine 14 to enable presentation of one or more instances of a page 13, such as a web page, on a display 15. For example, displayed page 13 may be obtained via a communications network 17 from a web server 16 and a data server 18. Web server 16 and data server 18, which may be separate or integrated components, respectively store web resources 20 and 22 and data items 24 and 26 that respectively define a first page instance 28 and a second page instance 30. For example, web resources 20 and 22 may include anything needed to construct a static portion of the page, e.g. an empty page template that can be filled with data, while data items 24 and 26 may include any content used to fill the page, e.g. one or more dynamic portions of the page. As such, all or some portion of web resources 20 and 22 are common to both first page instance 28 and second page instance 30, while all or some portion of data items 24 and 26 are unique to the respective page instance.

More specifically, portal component 12 communicates a received request 32, such as based on a user input or a launching of portal component 12, which identifies a requested instance of a page 34 to web engine 14. For example, the received request 32 may include a first portion that defines a web resource, such as a universal resource locator (URL), and a second portion that defines specific data to fetch, such as a query string. Web engine 14 includes a match determiner 36 that executes to determine if the requested instance of the page 34, as identified by request 32, corresponds to a stored document object model (DOM) 38 for the page. DOM 38 defines a tree or hierarchy of one or more nodes in child-parent relationship, including properties and/or attributes of the respective DOM node and its style attributes, which enables rendering of the page. If the requested instance of the page 34 corresponds to stored DOM 38, then an iterator component 40 identifies one or more static portion(s) 42 of DOM 38 that is/are common to both the requested instance of the page 34 and one or more stored instance(s) of the page 44. Optionally, it should be noted that DOM 38 may further include one or more dynamic portions 46 specific to each of the one or more stored instances of the page 44. For example, stored instance of the page 44 may correspond to first page instance 28, while requested instance of the page 34 may correspond to second page instance 30. Further, based on request 32, iterator component 40 identifies, creates, and stores one or more dynamic portions 48 specific to the requested instance of the page 34. As such, DOM 38 defines a relationship between different instances of a page and one or more respective corresponding dynamic DOM portions that are unique to each page instance, and further corresponding to one or more static DOM portions that are shared by more than one instance of the page. Thus, DOM 38 may be referred to as a shared DOM, as DOM 38 includes a static DOM portion that is the same for both the stored instance of the page 44 and the requested instance of the page 34.

Alternatively, if match determiner 36 determines that requested instance of the page 34 does not match or relate to any stored DOM, then match determiner 36 operates to create and store a new DOM 39 for that page. New DOM 39, which may have a similar structure as shared DOM 38, may then

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later be referenced by match determiner 36 to determine a match with subsequent requests for instances of pages.

In these aspects, shared DOM 38 may allow for faster rendering of the requested instance of the page 34, as web engine 14 does not need to reconstruct an entire DOM structure for a new instance of a page corresponding to a DOM already stored. Instead, web engine 14 can reuse static DOM portion 42, and only needs to perform the processing related to the one or more dynamic DOM portion(s) 48 corresponding to the requested instance of the page 34.

Additionally, computer device 10 may include a scripting engine 50 operable to perform scripting functionality. For example, web engine 14 interacts with scripting engine 50 to load script corresponding to the page, which scripting engine 50 executes to register the corresponding script functions. In response to an on load event received from web engine 14, scripting engine 50 further runs the page script and generates send calls to initiate the fetching of corresponding dynamic data for the instance of the web page. Further, after receiving the dynamic data, scripting engine 50 is operable to apply the data, for example via a DOM application program interface (API), and write the data to the corresponding DOM. Accordingly, based on the written dynamic data for the respective instance of the page, web engine 14 creates and stores one or more dynamic DOM portions in association with the respective page instance.

Additionally, computer device 10 includes a rendering engine 52 that interacts with web engine 14. For example, in response to a request from web engine 14, rendering engine 52 is operable to paint one or more parts of a respective page that correspond to one or more static DOM portions, and/or that correspond to one or more dynamic DOM portions for the respective instance of the page. Further, rendering engine 52 interacts with display 15 to present the painted portions of the page, thereby presenting a respective instance of the page.

Thus, by providing a DOM having a shared static portion, the described aspects may save communication resources in fetching web resources corresponding to each new instance of a page, or the described aspects may save processing resources in creating portions of the DOM by reusing the static DOM portion, or both.

Referring to FIG. 2, in one aspect, shared DOM 38 may be further explained as representing a template structure 60 defined by a plurality of nodes, such as nodes 62, 64, 66, 68, 70 and 72, and which further represents different instances of a page, such as first page instance 28, second page instance 30 and third page instance 74. Each page instance, e.g. 28, 30 and 74, share one or more common nodes, such as nodes 62, 64, 66, 68 and 70. The page data respectively associated with each node for each page instance, however, may differ. For example, page data 82, 84, 86, 88 and 90 respectively corresponds to nodes 62, 64, 66, 68 and 70 for first page instance 28, while page data 92, 94, 96, 98 and 100 respectively corresponds to nodes 62, 64, 66, 68 and 70 for second page instance 30, while page data 102, 104, 106, 108 and 110 respectively corresponds to nodes 62, 64, 66, 68 and 70 for third page instance 74. Further, it is noted that some page instances may have more or less nodes than other page instances. For example, in FIG. 2, third page instance 74 includes an additional node 72, having respective page data 112, which is not found in any other page instances.

Shared DOM 38 defines relationships between nodes, page data, and page instances that provide a simple and efficient mechanism to identify and construct the different page instances. For example, shared DOM 38 identifies all of the nodes for the respective page instances 28, 30 and 74, including the shared nodes 62, 64, 66, 68 and 70 and their respective

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relationship to one another, as well as any nodes unique to any instance, such as node 72. Further, shared DOM 38 includes static DOM portions 122, 124, 126, 128 and 130, e.g. common portions, corresponding to each node as well as dynamic DOM portion or dynamic page data corresponding to each node, such as dynamic data 82, 92 and 102 respectively corresponding to instances 28, 30 and 74 for node 62, dynamic data 84, 94 and 104 respectively corresponding to instances 28, 30 and 74 for node 64, dynamic data 86, 96 and 106 respectively corresponding to instances 28, 30 and 74 for node 66, dynamic data 88, 98 and 108 respectively corresponding to instances 28, 30 and 74 for node 68, and dynamic data 90, 100 and 110 respectively corresponding to instances 28, 30 and 74 for node 70. Additionally, shared DOM 38 includes dynamic DOM portions for unique nodes, such as dynamic data 112 corresponding to third page instance 74 for node 72.

Referring to FIG. 3, in one aspect, computer device 10, such as a mobile or cellular phone, may include a processor 150 for carrying out processing functions associated with one or more of components and functions described herein. Processor 150 can include a single or multiple set of processors or multi-core processors. Moreover, processor 150 can be implemented as an integrated processing system and/or a distributed processing system.

Computer device 10 may further include a memory 152, such as for storing local versions of applications being executed by processor 150, and/or for long term storage of data, instructions, and/or applications not currently being executed or utilized by processor 150. In one aspect, memory 152 may further comprise derivative cache 155. Upon receipt of content that is intended to be cached, computer device 10 may further process the received content to generate derived content and store the derivative content 157 in the derivative cache 155. In one aspect, this processing may assist to efficiently facilitate subsequent usage of the cached content through pre-preparation of derivative content 157 that is often used. In another aspect, memory 152 may include structured cache 159. Structured cache 159 may allow for storage of content in a manner such that retrieval may be selectively done through choosing select known portions of the content for retrieval. In one aspect, structured cache 159 is organized in such a way as to allow selected known portions of a content item stored in the structured cache 159 to be retrieved without requiring retrieval of the entire content item. Memory 152 can additionally store protocols and/or algorithms associated with estimating and/or utilizing a channel (e.g., performance based, capacity based, etc.). In one aspect, memory 152 may further comprise raw content storage 151. Raw content storage 151 may allow for storage of received raw content.

It will be appreciated that the data store (e.g., memory 152) described herein can be either volatile memory or nonvolatile memory, or can include both volatile and nonvolatile memory. In one aspect, a dual memory model may be used where a first layer is a file system based non-volatile memory and the second layer is a heap structure volatile memory. In such an aspect, raw received content may be stored in the first layer and derivative content may be stored in the second layer. Furthermore, in such an aspect, the second layer may be accessed more quickly than the first layer. By way of illustration, and not limitation, nonvolatile memory can include read only memory (ROM), programmable ROM (PROM), electrically programmable ROM (EPROM), electrically erasable PROM (EEPROM), or flash memory. Volatile memory can include random access memory (RAM), which acts as external cache memory. By way of illustration and not limitation, RAM is available in many forms such as synchronous RAM

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(SRAM), dynamic RAM (DRAM), synchronous DRAM (SDRAM), double data rate SDRAM (DDR SDRAM), enhanced SDRAM (ESDRAM), Synchlink DRAM (SLDRAM), and direct Rambus RAM (DRRAM). The memory **152** of the subject systems and methods may comprise, without being limited to, these and any other suitable types of memory.

Further, computer device **10** may include a communications component **154** that provides for establishing and maintaining communications with one or more entities utilizing hardware, software, and services as described herein. Communications component **154** may carry communications between components on computer device **10**, as well as between computer device **10** and external devices, such as devices located across a communications network and/or devices serially or locally connected to computer device **10**. For example, communications component **154** may include one or more buses, and may further include interfaces, one or more transmitters or transmit chain components and one or more receivers or receive chain components operable for interfacing with external devices. For example, such transmitter and receivers may enable wired or wireless communications according to one or more technologies or protocols.

Computer device **10** may additionally include a user interface component **156** operable to receive inputs **158** from a user of computer device **10**, and further operable to generate outputs **160** for presentation to the user. User interface component **156** may include one or more input devices, including but not limited to a keyboard, a number pad, a mouse, a touch-sensitive display, a navigation key, a function key, a microphone, a voice recognition component, any other mechanism capable of receiving an input from a user, or any combination thereof. Further, user interface component **156** may include one or more output devices, including but not limited to a display, a speaker, a haptic feedback mechanism, a printer, any other mechanism capable of presenting an output to a user, or any combination thereof.

Additionally, as noted above, computer device **10** may include portal component **12**, which may be one or any combination of a web browser, a widget or a mobile widget, or a web application. Portal component **12** is operable to interface with a user of computer device **10**, as well as with other components of computer device **10**, to enable rendering of a web page.

Web engine **14**, as discussed above, manages the determination of matches for DOMs, and the creation and storage of DOMs. Optionally, in some aspects, web engine **14** may include a fetch manager **162** to manage timing and performance of fetch operations. For example, fetch manager **162** may enable pre-fetching of content for the page having a link that was just clicked from a referring page, where the referring page includes the URLs to perform the pre-fetching. In an aspect, for instance, fetch manager **162** may execute a pre-fetch discovery call in the javascript of the referring page. In another aspect, for instance, fetch manager **162** may tag or order URLs to fetch on a page so these tags or URLs can be processed in page rendering prior to receiving a request for the respective page. For example, fetch manager **162** may include algorithms or functions to determine relationships between pages, e.g. adjacent pages in a list, adjacent pages in a hierarchy, etc., in order to determine what to pre-fetch and when to pre-fetch. In other aspects, the described apparatus and methods may include in the HTML head of a current page a manifest of the known URLs, which will be analyzed by fetch manager **162** for pre-fetching. In another aspect, the described apparatus and methods may include in the HTML head of a referring page a structured manifest of the URLs for

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each reachable page, which will be analyzed by fetch manager **162** to execute pre-fetching for each reachable page. In further derivation of this aspect, the described apparatus and methods may separate out the local 'next page' manifest from the page metadata, inserting this in as a getPageManifest( ) call to a GRS. This will allow the server to tune the prefetch order without having to update the page's xhtml page. This is another URL, so expiry and ifmodified-since can control the caching of this 'caching metadata' resource. In another aspect, the described apparatus and methods may include retrieving this metadata with a broader pre-fetch policy call. Such a policy update may include all the pre-fetch ordering for the whole template set. The pre-fetch ordering may be keyed and fetched initially with the bootstrap manifest.

Optionally, in some aspects, web engine **14** may include a derivation manager **164** to pre-derive a DOM or portions of a DOM prior to request of the respective instance of the page. For example, a big part of the rendering delay has to do with getting the web document parsed into a DOM and ready to render. Derivation manager **164** includes algorithms or functions that provide a layer in managing the derivation of web pages into DOM and caching the DOM prior to when that page is needed. Derivation manager **164** enables such derivation occur in a smart way, likely not when first downloaded via directive from the manifest, but instead the derivation and caching may occur when web engine **14** is relatively unused and the probability of the respective page being needed is high. For example, the algorithms or functions of derivation manager **164** may determine relationships between pages, e.g. adjacent pages in a list, adjacent pages in a hierarchy, etc., in order to determine what to pre-derive and when to pre-derive one or more pages.

It should be noted that fetch manager **162** and derivation manager **164** may be combined in the same computer device **10** to improve the performance for first runs of a page in a session.

Computer device **10** can further comprise content handler **166** to assist in processing of content prior to caching. In one aspect, content handler **166** allows the computer device **102** to determine whether to generate derivative content **157** from the received raw content **151**. Further, content handler **166** may receive processing instructions **168** from a communications network. In such an aspect, the communications network may provide processing instructions **168** along with content to be stored at computer device **102**. In one aspect, processing instructions **168** may allow some server side control, such as by the communications network, that passes to the computer device **102** in order to perform transformations or the like on the raw content **151** at the computer device **102** in a manner that may be more efficient than without the processing instructions **168**. In one aspect, processing instructions **168** may facilitate associating derivative content **157** with received, raw content **151**, so as to allow efficient subsequent retrieval. For example, processing instructions **168** may be transmitted with an image and may provide instructions for remapping the image pixels. As such, the size of the content that is transferred with the processing instructions may be small. And once the small-sized raw content and processing instructions are received by the computer device **102**, the processing instructions **168** facilitate expanding out the content into a richer image or a more rich set of content. Content handler **166** may further include structure reference **169** to assist in the processing of received content. Structure reference **169** may process received content to facilitate structured storage in structure cache **159**.

Scripting engine **50**, such as a javascript engine, manages the registering of script functions and the running of script of

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a given instance of a page. Rendering engine 52 generates or paints all or portions of a given instance of a page, and communicates the results to a component of user interface 156, such as displayed page instance 13 presented on display 15 (FIG. 1).

Turning now to FIG. 4, in operation, in one aspect, a method 170 of rendering a page includes receiving, at a computer device, a request for a requested instance of a page (Block 172).

The method further includes determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory. The DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page (Block 174).

Further, the method includes referencing a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory. The dynamic portion is unique to the requested instance of the page (Block 176).

The method also includes storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM (Block 178). Optionally, the method further includes rendering the requested instance of the page according to the static portion of the DOM and the dynamic portion of the DOM corresponding to the requested instance of the page (Block 180).

Referring to FIGS. 5 and 6, in an aspect, a method of rendering a respective first and second instance of a page include requesting a first instance of a page (202, 204, 302, 304), such as based on a user input or launching of a portal application. The method further includes the web engine determining if the instance of the page corresponds to a DOM stored in memory or a cache (206, 306). At 207, if the instance of the page corresponds to a DOM stored in memory or a cache, e.g., a pre-derived DOM, the method continues to the paint process (218). However, if the instance of the page does not correspond to a DOM stored in memory or a cache, a corresponding GET and response is respectively transmitted to and received from a web server (208, 210). The response includes, for example, xhtml, css, and javascript.

In some aspects, at 211, pre-processing of the received content may be performed, e.g., deriving the received content to generate derivative content. In one aspect, raw content obtained from the web server may be accompanied by processing instructions. Upon receipt of the raw content from the web server, a content handler may determine whether additional processing may be performed prior to or contemporaneously with caching the received raw content. In one aspect, the processing instructions assist in at least determining whether to further process the received raw content. In another aspect, the received raw content may be stored in a structured cache as determined by known structure associated with the raw content, such as may be defined by structure reference, server generated entry points, or the like. Once the content handler determines that at least a portion of the received, raw content may be processed, the content handler processes the selected portion of the received, raw content to generate the derivative content. The derivative content may be stored in a derivative cache. In one aspect, the derivative content is further associated with the received raw content and stored accordingly. For example, the derivative content may include compiled javascript and/or compiled css for subsequent use in rendering a respective first and second instance of a page. As discussed below, FIGS. 7-9 illustrate various methodologies for pre-processing the content.

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Then, the response data is stored in a cache (212), and a static DOM portion is created and stored (214). Creating and storing the static DOM portion may include deriving the content from the response and transforming the content into a form capable of being processed by the web engine. For example, deriving the content from the response may include parsing the response, e.g., xhtml code, and creating a DOM from the parsed information. Further, rules may be constructed and applied to the DOM for aiding in the creation of the static DOM. The rules may include, for example, CSS Rules, among other types of rules. It should be appreciated that the static DOM may be stored in a memory or a cache for later use. In one aspect, all or a portion of the static DOM is pre-processed (211), and thus the static DOM portion may include derivative content. Alternatively, for the second instance, the static DOM portion is found and used (316). In both cases, a paint process is started to paint and display one or more static DOM portions. More particularly, the web engine starts the paint process (218, 318) and initiates the rendering engine to paint the static portion (220, 320). The rendering engine forwards the painted static portion (222, 322) to the display to display one or more static DOM portions (224, 324). Note that the timing of this painting process may vary. In addition, the derived css content (211) may be used for creating static structures and text during the painting process (220, 320).

Further, after obtaining the response or the stored static DOM portion, a load script operation is initiated (226, 326), where the scripting engine registers script functions (228, 328), receives an onload event (230, 330), and then runs a page script (232, 332). The derived javascript (211) may be used during the scripting functions (228, 232, 328, 332). An XHR send event (234, 334) is then transmitted to the web engine, which checks to see if the data is already stored in a cache (236, 336). If so, at 237 and 337, the stored data can be utilized and passed to the scripting engine (244, 344). If not, then a data fetch and response are respectively transmitted and received from a data server (238 and 240, 338 and 340). This can be an XHR call (238) and XHR results (240). In some aspects, at 241 and 341, pre-processing of the received content may be performed, as discussed above in 211. As discussed below, FIGS. 7-9 illustrate various methodologies for pre-processing the content.

The response data is stored in a cache (242, 342), and the results are passed to the scripting engine (244, 344), which applies the data via a DOM API and writes the data to the cache in the web engine (246 and 248, 346 and 348). The web engine then creates and stores a dynamic DOM portion for the given instance for one or more dynamic portions of the data (250, 350). The web engine may buffer this DOM portion (252, 352), as painting operations can be resource expensive. Then, the web engine initiates a paint operation, similar to the above operation for the static portion, which results in the given instance of the page being created. The web engine starts the paint process (254, 354) and initiates the rendering engine to paint the static portion (256, 356). The rendering engine forwards the painted static portion (258, 358) to the display for displaying one or more static DOM portions (260, 360) resulting in the given instance of the page being created (262, 362). Additionally, it is noted that the derived css content (241, 341) may be used for creating static structures and text during the painting process (256, 356).

Optionally, in some aspects, the methods of FIGS. 5 and 6 may include one or more pre-fetching operations (264, 364) as described above with reference to fetching manager 162 (FIG. 3). It should be noted that the timing in the sequence of operations of FIGS. 5 and 6 of the pre-fetching operation may



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be changed relative to the illustrated action, based on the determinations of when such pre-fetching is desired. Further, it should be noted that the pre-fetching operation may further include additional GETs and responses, and/or XHR calls and results, and corresponding prior and subsequent processing, as described above.

Optionally, in some aspect, the methods of FIGS. 5 and 6 may include one or more pre-derivation operations (266, 366) as described above with reference to derivation manager 164 (FIG. 3). It should be noted that the timing in the sequence of operations of FIGS. 5 and 6 of the pre-derivation operations may be changed relative to the illustrated action, based on the determinations of when such pre-derivation is desired. Further, it should be noted that the pre-derivation operations may further include additional GETs and responses, and/or additional XHR calls and results, and corresponding prior and subsequent processing, as described above.

Turning now to FIG. 7, exemplary method 1000 for facilitating efficient local caching is illustrated. At reference numeral 1002, raw data is received. In one aspect, the data may be accompanying by processing instructions. The data may be received by a computer device or the like and the data may originate from a server, communications network etc. For example, in an aspect, the raw data may include css and javascript.

At reference numeral 1004, the method includes determining whether the received data is a candidate for local processing. For example, the received data may include processing instructions prompting further processing. In another aspect, the received data may be of a known data type prompting further processing, such as css or javascript. If it is determined that no further processing is required, then at reference numeral 1006, the received data may be cached. Additionally or optionally, in one aspect, received data may be cached irrespective of whether the data is a candidate for further processing. By contrast, if at reference numeral 1004 it is determined that further processing is prompted, then, at reference numeral 1008, locally derived content is generated from the received content. In one aspect, processing instructions may guide the content handler in generating the derivative content. For example, a received image may be processed to generate one or more sizes commonly used on a computing device. In another example, a received program file may be processed to generate a compiled program for subsequent use by a computing device. In still another example, a received font type may be processed to generate various commonly used color and/or size variations for subsequent use by a computing device. At reference numeral 1010 at least the derivative content is stored in the cache. In another aspect, the derivative content and the received content are stored and associated to aid in subsequent retrieval. In one aspect, caching of raw data and one or more derived content items may improve perceived application performance by eliminating processing requirements after retrieval for derivative content items. In still another aspect, the processing instructions are stored with the derivative content and the received content and used to associate the derived and received content.

Turning now to FIG. 8, exemplary method 1100 for facilitating content modification through processing instructions before storage in cache is illustrated, according to one aspect. In one aspect, at reference numeral 1102, a computing device may request, fetch or the like content to be stored in cache. In such an aspect, the request may be accompanied with negotiation instructions. For example, the request may be for an image, with accompanying instructions providing a possible pixel range of a preferable image. Generally, at reference numeral 1104, raw data is received. Such data may be accom-

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panying by processing instructions. In one aspect, these processing instructions are generated at least in part in response to the request negotiation instructions. The data may be received by a computer device or the like and the data may originate from a server, communications network, etc.

Next to be described, at reference numeral 1106, it is determined whether the received data is a candidate for local processing by analyzing the accompanying processing instructions. If the processing instructions do not prompt further processing, then at reference numeral 1108, the received data may be cached. By contrast, if at reference numeral 1106 processing instructions prompt additional processing, then, at reference numeral 1112, a content handler may be provided with the processing instructions and the received content. At reference numeral 1112, locally derived content, e.g. derivative content, is generated from the raw content using processing instructions as a guide. As such, a server or the like may facilitate processing of raw content after transmission. For example, a received image may be processed to generate to an image with less granularity by the processing instructions prompting the content handler to smooth gradations of the received image.

At reference numeral 1114, at least the derivative content is stored in the cache. In another aspect the derived and received content are stored and associated to aid in subsequent retrieval. In still another aspect, the processing instructions are stored with the derived and received content and used to associate the derived and received content.

Turning now to FIG. 9, exemplary method 900 for facilitating structured storage in cache is illustrated. Generally, at reference numeral 902, semantically opaque data is received. In one aspect, the data may be accompanying by server generated entry points to allow structured retrieval of selected portions. In another aspect, the data may be of a known structure. The data may be received by a computer device or the like and the data may originate from a server, content provider, etc.

Next to be described, at reference numeral 904, it is determined whether the received data may be associated with a known structure. For example, the received data may include server generated entry points or may be of a known structure. If it is determined that the data is not structured in a manner allowing further processing, then at reference numeral 906, the received data may be cached. By contrast, if at reference numeral 904 it is determined that further processing is prompted, then, at reference numeral 908, the data structure may be determined. For example, certain media types may be defined with known structures that allow for processing to facilitate selective subsequent retrieval. At reference numeral 910, the received structured content is stored with reference to its known content.

In one aspect, at reference numeral 912, a request for a portion of structured content may be received. In such an aspect, at reference numeral 914 the requested portion of the structured content may be retrieved. For example, information associated with the manufacturer, or the title, or the like may be selectively retrieved from the structured content in the cache without removal of the entire content item.

One illustrative example of a mobile shopping application executed by a mobile phone in accordance with an aspect is illustrated in FIGS. 10-13. Turning now to FIG. 10, in an aspect, a main page 500, e.g., a first instance of a page, may be requested by a user and displayed on the mobile device as discussed above in relation to FIGS. 1-7 above. Main page 500 may include a catalog listing 504 with information relating to the various items in the catalog. Catalog listing 504 may include, among other information, a listing of categories of



data in the catalog, e.g., **506a-506n**, promotional information for items in the catalog, previews, and/or descriptions of items in the catalog, or items to purchase from the catalog. If a user wants to view a different catalog listing, a user may move to a different catalog listings in the shopping application by selecting button **502**, for example. Alternatively, or in addition, a user may select, for example, one of the categories of data in the catalog, e.g., “New This Week” **506c**, and move to a catalog page for the selected category. An example of a catalog page, e.g., a second instance of a page, is illustrated in FIG. 11.

Referring now to FIG. 11, in an aspect, catalog page **600** may be requested by a user and displayed on the mobile device, e.g., the user selects catalog page **600** from the main page **500** (FIG. 10). When catalog page **600** is requested, the mobile device may determine whether catalog page **600** has similar structures corresponding to main page **500** and/or other pages in the shopping application. Upon determining that the catalog page **600** has similar structures as main page **500**, the mobile device may retrieve and reuse the similar structures of catalog page **600** from the DOM of main page **500**. In addition, the mobile device may determine that catalog page **600** has structures that are different from main page **500** and may create a DOM for the items unique to catalog page **600**.

Catalog page **600** may include a title **604**, e.g., “New This Week,” describing the listing of items to purchase **608a-608n** and/or categories of items **606**. Categories may include, for example, games, music, videos, best sellers, featured items, and/or recommended items, among other categories. It should be appreciated that title **604** may correspond to the selection the user choose on the main page **500** (FIG. 10). In addition, the items to purchase **608a-608n** may include: a name **612a-612n** describing the item for purchase; a price **614a-614n** for the item; an icon **610a-610n** illustrating and/or describing the item for purchase; displayed ratings **616a-610n** for the item (e.g., stars or text summarizing data relating to the quality and/or performance of the item for purchase); and the supplier for the item, among other information relating to the items for purchase. It should be appreciated that the items for purchase may include, for example, games, music, videos or books, among other items.

For example, the mobile device may determine that the title **604**, the listing of items to purchase **608a-608n** and/or categories of items **606** have similar structure as features in main page **500** (e.g., title **504**, button **502** and listings **506a-506n**) and may retrieve and reuse the similar structures from main page **500** DOM. In addition, the mobile device may determine that the name of the title **604**, e.g., “New This Week”, names for the games **612a-612n**, icons for the games **608a-608n**, prices for the games **614a-614n**, and/or the ratings for the games **616a-616n** are unique to catalog page **600**, and thus, may create a dynamic DOM for the features that are unique to catalog page **600**.

Therefore, the mobile device is creating a dynamic DOM for the portions of catalog page **600** that are unique to catalog page **600** and reusing similar structure and/or instances from the static DOM of main page **500**. Thus, allowing for faster rendering of catalog page **600** since the mobile device does not need to reconstruct an entire DOM structure for catalog page **600**.

If a user wants to view a different catalog page or return to the main page **500**, the user may move to different catalogs page in the shopping application by selecting button **602**, for example. Alternatively, or in addition, a user may select, for example, one of the categories and/or items listed on the catalog page **600**, e.g., the game “Game #5 Name” **612e**, and

move to an item page, e.g., another second instance of a page. Examples of an item page, e.g., a second instance of a page, are illustrated in FIGS. 12 and 13.

Referring now to FIG. 12, in an aspect, item detail page **700** may be requested by a user and displayed on the mobile device, e.g., the user selects item detail page **700** from catalog page **600** (FIG. 11). When item detail page **700** is requested, the mobile device may determine whether item detail page **700** has similar structures and/or instances corresponding to catalog page **600**, main page **500** and/or other pages in the shopping application. As discussed above in relation to FIG. 11, the mobile device may retrieve and reuse the similar structures of catalog page **600** and/or main page **500** from the DOMs of main page **500** and/or catalog page **600**. In addition, the mobile device may create a DOM for the portions of item detail page **700** that do not match the structure or items in catalog page **600** and/or main page **500**.

For example, the mobile device may determine that button **702**, game name **706**, icon **704**, price **710** and ratings for the game **708** on the item detail page **700** may have similar structure as features as catalog page **600** and may retrieve and reuse the similar structures from catalog page **600** DOM. In addition, the mobile device may create a DOM for the portions of item detail page **700** that do not match the structure or items in catalog page **600** and/or main page **500**, e.g., rate this item option **720**, more like these recommendations **716**. Therefore, the mobile device is creating a dynamic DOM for the portions of item detail page **700** that are unique to item detail page **700** and reusing similar structure and/or instances from catalog page **600** and/or main page **500**. Thus, allowing for faster rendering of item detail page **700** since the mobile device does not need to reconstruct an entire DOM structure for item detail page **700**.

If a user wants to view the previous page, the user may select button **702** to return to the previous page in the shopping application. Alternatively, or in addition, a user may select, for example, another item on the item detail page **700**, e.g., the game “Guitar Hero III” **718**, and move to another item detail page, e.g., item detail page **800** illustrated in FIG. 13.

Turning now to FIG. 13, illustrated is another example of an item detail page **800** in accordance with an aspect. As discussed above in relation to FIG. 12, the mobile device may determine whether item detail page **800** has similar structures and/or instances corresponding to item detail page **700**, catalog page **600**, main page **500** and/or other pages in the shopping application. The mobile device may retrieve and reuse the similar structures of item detail page **700**, catalog page **600** and/or main page **500** from the DOMs of item detail page **700**, main page **500** and/or catalog page **600**. In addition, the mobile device may create a dynamic DOM for the portions of item detail page **800** that do not match the structure or items in item detail page **700**, catalog page **600** and/or main page **500**. For example, in this case, the static DOM portion may comprise a same layout of item detail page **700**, while the dynamic data items, such as the game name **806**, the game rating **808** and the price for the game **810**, are represented by a dynamic DOM portion.

Referring to FIG. 14, illustrated is an apparatus **400** that renders pages, such as web pages, received from a web server and data server via a content provider. In some aspects, for example, apparatus **400** can reside within a mobile device. As depicted, apparatus **400** includes functional blocks that can represent functions implemented by a processor, or software, or combination thereof (e.g., firmware). Apparatus **400** includes a logical grouping **402** of electrical components that facilitate receiving web resources and data corresponding to a

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page, and rendering an instance of the page. Logical grouping 402 can include a means for receiving, such as at a computer device, a request for a requested instance of a page 404. Further, logical grouping 402 can include a means for determining if the requested instance of the page corresponds to a document object model (DOM) for the page stored in a memory 406, wherein the DOM stored in memory corresponds to a stored instance of the page and comprises a static portion that is the same for both the stored instance and the requested instance of the page. Also, logical grouping 402 can include a means for retrieving a dynamic portion of the DOM corresponding to the requested instance if the requested instance of the page corresponds to the DOM stored in the memory 408, wherein the dynamic portion is unique to the requested instance of the page. Additionally, logical grouping 402 can include a means for storing the dynamic portion of the DOM corresponding to the requested instance of the page in a relationship with the static portion of the DOM 410. Optionally, logical grouping 402 can include a means for rendering the requested instance of the page according to the static portion of the DOM and the dynamic portion of the DOM corresponding to the requested instance of the page 412. Thus, apparatus 400 can efficiently reuse static DOM portions in rendering a page, and create and store a shared DOM having relationships defining one or more dynamic DOM portions corresponding to a respective one or more instances of a page.

Additionally, apparatus 400 can include a memory 414 that retains instructions for executing functions associated with electrical components 404, 406, 408, 410 and optionally 412. While shown as being external to memory 414, it is to be understood that electrical components 404, 406, 408, 410 and optionally 412 can exist within memory 414.

In addition to the above mentioned caching and processing techniques, further aspects provide systems, methods, and devices for improving the performance of a browser through reuse of HTML computations in addition to the HTML code, with the HTML computations linked or indexed to corresponding DOM tree structures. In loading a web page, browsers typically execute two high level tasks: fetching the HTML code through the Internet (herein "network element") and performing HTML computations to process the content of the HTML code (herein "computation element"). Conventional browsers improve the webpage rendering process by caching the HTML code received from particular URLs in a local memory, thereby saving the time to download the HTML and improving the network element. By caching the HTML code, browsers may begin rendering a page as soon as they receive a request to access a uniform resource locator (URL) or uniform resource identifier (URI) for which corresponding HTML code is cached. Thus, conventional browsers store HTML code such that they may begin rendering a page as soon as they determine that a requested URL/URI matches a URL/URI component having a link to the stored HTML code as if the HTML had been received over the internet. However, such browsers fail to address the computation element, requiring the computations to be reperformed each time the same page is rendered. As a result, conventional browsers only improve rendering times to the extent that the network element is a performance bottleneck.

Fetching HTML code is a performance bottleneck if data transmission rates are slower than local processing speeds. This typically occurs when a lot of data needs to be fetched over a network having limited bandwidth. However, in recent years, network bandwidths have improved dramatically. This is evidenced by 3.5 G and 4 G mobile networks becoming more and more available, providing a bandwidth in excess of

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14.4 Mbps. Also, once the HTML code is cached for a URL, conventional browsers are unable to render pages any faster, which can appear to the user that upgrading to a faster network does little to improve webpage rendering times. Web pages are becoming increasingly more complex. Modern web pages require a substantial amount of computation to parse, format, and render the content of received web pages. Thus, the bottlenecks in rendering webpages has shifted from the network element to the computation element.

The various aspect provide for the efficient mapping and association of HTML rendering computations to their DOM tree structures so that the computations calculated for a portion of one page may be efficiently re-used in rendering one or more portions of subsequent pages based on structural similarities, rather than based on the URLs and/or URIs.

Web browsers generate pages for display by processing HTML code to calculate and define all of the elements that go into the display. The time required to calculate the style, format, and layout requirements of the webpage elements is often substantial. For example, the combination of layout calculations and style formatting typically accounts for more than half of the total computation time in local Web page processing. Additionally, the process of computing style properties and applying them to the DOM elements is typically a recursive and time-consuming process that must be performed every time a web page is requested and/or rendered. The various aspects eliminate these redundant and time-consuming processes by storing the computations calculated for a first page and reusing the stored calculations to render a second page having the same or similar DOM tree structure (i.e., isomorphic), without requiring any association between the web page URLs of the first and second pages.

The aspects discussed above with reference to FIGS. 1 and 2 store the DOM tree so that different instances of the same page (sharing a URL and/or URI) may share static portions of the same DOM tree. In those aspects, when a unique instance of a page (e.g., "itemdetail" page) is requested, page data (e.g., the hyper text markup language (html), cascading sheet style (css), and javascript (js)) may be fetched and used to create static portions of a DOM tree. These static portions may be stored in a cache such that they can be reused. That is, when a second instance of the stored page is requested, the static DOM portions of the first instance are reused and one or more dynamic portions are created specifically for the second instance. As a result, these aspects allow for defining a DOM so that the portions of the DOM may be reused for rendering different instances of the same page. The aspects described below with reference to FIGS. 15-20 extend the capabilities to enable reuse of HTML computations even when the URLs or URIs are different.

In rendering a web page, browsers first parse the HTML code (whether received via a network or recalled from memory) to generate a DOM tree. Conventional browsers, as well as browsers of the various embodiments when the DOM tree does not match any DOM tree structures in memory, then process the DOM tree to perform the computations required to define the features and characteristics of the page to be rendered. These computations may include, for example, computing dimensions and styles for each sub-element that is to be displayed on the page. There are many well known computations that may be required for any given web page. These computations may include calculating the layout, identifying styles, performing CSS matching, and other operations requiring processor and/or processing intensive computing. In various aspects, these computations along with the corresponding portions of the DOM tree are stored in memory. Then each time a page is rendered, the generated

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DOM tree is compared to cached DOM trees to determine if there are any matches before the computations are performed. If matching DOM tree structures are identified in memory, the corresponding HTML calculation results are recalled in memory and reused, and only those portions of the page's DOM tree that is not matched to stored tree are processed to complete the HTML calculations needed to render the page. The browsers may identify structural similarities between the store DOM tree portions and the DOM tree of the requested page using the well known tree isomorphism algorithms. Thus, this reuseability determination is made independent of URLs and/or URIs.

The aspects described below further improve browser performance by storing the resultant computations in a DOM tree in memory and recognizing based on DOM tree structures to identify portions of the stored computations that may be reused to render an accessed webpage, thereby increasing the amount of HTML rendering calculations available for reuse by the browser. To achieve this, in addition to caching the static and dynamic portions of the DOM tree, the actual computations are stored in memory. In various aspects, the resultant computations may be cached such that the cached computations are indexed to their DOM tree (i.e., the DOM tree that was executed in accomplishing the computations). In an aspect the results are stored in memory in the form of key-value (i.e., a tag and a value) pairs. The key or tag identifies the tree structure elements, while the value is the results of the HTML calculations for the element. By indexing the computations to the DOM tree, the cached calculations may be re-used when rendering any page having a structurally similar DOM tree portion, independent of the URL or URI associated with either the originally cached page or the page to be rendered. Storing the computations indexed to the DOM tree also allows the structure of stored DOM tree to be quickly analyzed without requiring any special tags, information regarding URLs and/or URIs, or any other additional identification mechanisms.

The various aspects use various well known tree isomorphism algorithms to recognize and identify the isomorphic portions of the DOM tree of the page being rendered and the DOM tree portions stored in memory (i.e., portions sharing a similar tree structure) to recognize cached computations that can be reused. For example, the browser may use the well known algorithms, such as Alogtime, Aho, Hopcroft, Ullman, and other isomorphism algorithms described in "The Design and Analysis of Computer Algorithms," Addison-Wesley, 1974, the entire contents of which are incorporated herein, for tree isomorphism to identify matching DOM tree portions.

When a browser recognizes that portions of a current DOM tree match portions of a stored DOM tree or stored DOM tree portions, cached computation results corresponding to the identified portions may be quickly and efficiently recalled from memory. This may be accomplished by storing the computation results in the form of key values and input values. In these aspects, the key values and input values used to create the cached computation results may be compared to key values and input values of a current page being rendered to determine if the values are the same so that one or more portions of the stored computation results can be reused. If one or more portions of stored computations are determined to be reusable, the stored computation values are recalled from memory and used by the browser. When all reusable HTML computations for the page have been recalled from memory and all other computations performed by the browser, the retrieved and performed computation results may be used to display the page. Combining this capability with conventional HTML caching capabilities enables

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browsers to very rapidly display a page without downloading or computing a newly requested HTML page.

FIG. 15 illustrates a sample portion of a DOM tree 1500 generated by a browser parsing HTML code for a requested webpage. As illustrated in FIG. 15, when parsing HTML code, a browser may create a DOM element and/or node for each heading. In the illustrated example, the HTML code contains a header section (e.g., <HEAD>...</HEAD>) and a body section (e.g., <BODY>...</BODY>). The body section contains at least one Div section and at least one Span section, as illustrated by the Div and Span nodes in the DOM tree 1500. Each of the Div and Span nodes may also contain sub-sections, as illustrated by the paragraph section of the Div section. In the process of accomplishing the calculations for rendering the page, the DOM tree elements (e.g., Body, Div, Paragraph, etc.) may be traversed to compute the properties and characteristics of the various page components. For example, for computing the layout of a requested page, the DOM tree may be traversed to extract the absolute values for the heights, widths, and positions (e.g., h=50, w=50, x=500, y=10) of each element, which are typically dependent on run-time and environmental factors (e.g., window size) and cannot be determined ahead of time. In the various aspects, these calculated positions values may be then stored in a memory linked to the DOM tree for reuse in rendering future pages including the same or similar calculations.

FIG. 16 illustrates that calculated values may be stored for each element in the DOM tree 1500. In the illustrated example, an absolute position value representing the height, width, horizontal position (X) and vertical position (Y) of each element may be stored in memory 1610 as a hash-table, hash-map, linked-list, binary tree, and/or associated array. In various aspects, the information may be stored in the memory 1610 as a hash-table and/or hash-map such that the key-value pairs of the stored information map to the corresponding node in the DOM tree. For example, the key-value pairs may be stored such that the key element identifies a DOM tree element and locates (e.g., via the hash function of the hash map) the corresponding value element (e.g., the absolute position value of the DOM element). In various aspects, the hash-table and/or hash-map may be well-dimensioned such that the number of instructions required to identify a value (e.g., absolute position) is independent of the number of elements in the DOM tree. In various aspects, the hash-table and/or hash-map may be used to store the DOM trees and their associated properties in a single unified data structure. Other data structures or combination of data structures known in the art may also be used.

FIG. 17 illustrates an aspect method 1700 for creating, processing, and storing the DOM tree on a first execution of a browser or first rendition of a particular web page having an unidentified DOM structure. In method 1700, the browser may receive HTML code from a remote or local server corresponding to a desired web page in block 1702. The browser may parse the received HTML and create the DOM tree in block 1704. In block 1706, the browser may process the DOM tree to complete all the necessarily computations. In block 1708, the browser may cache the computation results in memory, and compose the DOM tree and/or processed HTML code for outputting to a display in block 1710. In block 1712, the browser may display the composed and processed HTML code along with all the associated images and files on an electronic display of the computing device on which the browser is running.

FIG. 18 illustrates an aspect method 1800 for creating, processing, storing, and/or retrieving portions of a DOM tree on a subsequent execution of the browser. In method 1800 in

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block **1802**, the browser may receive HTML code from a server and/or recall HTML code from cache memory. In block **1804**, the browser may parse the HTML code and create at least a portion of a DOM tree for the received HTML code. In determination block **1806**, the browser may determine whether the generated portion of the DOM tree matches any portions of one or more DOM trees stored in memory by determining whether the DOM tree structures are isomorphic. In various aspects, the browser may make this determination by evaluating the indices of one or more stored DOM trees. In various aspects, the browser may check hash-keys associated with the generated portion of the DOM tree against the hash-keys of one or more portions of the DOM trees stored in memory. In various aspects, the browser may execute, or initiate the execution of, more or more isomorphic algorithms to determine whether portions of the generated DOM tree match any of the portions of a DOM tree stored in memory. The execution of the isomorphic algorithms in determination block **1806** may determine if portions of the generated DOM tree are structurally identical and/or structurally similar to portions of the DOM trees stored in memory.

Returning to FIG. **18**, if it is determined that the generated portion of the DOM tree does not match the structure of any of the DOM trees stored in memory (i.e., determination block **1806**="No"), in block **1808**, the browser may process the generated portion of the DOM tree and perform the associated computations (e.g., calculate the absolute positions of the elements, styles, perform CSS matching, etc.). In block **1810**, the browser may cache the computation results with the results indexed to the executed portions of the DOM tree.

If, on the other hand, it is determined that the generated portion of the DOM tree is structurally the same as and/or structurally similar to any of the portions of the DOM trees stored in memory (i.e., determination block **1806**="Yes"), in block **1812** the browser may recall from memory the cached computation results corresponding to the matched DOM index. In determination block **1814**, the browser may determine if the key and/or input data of the matched portions stored in memory are the same as the key and/or input data of the generated portions, indicating that the stored computations are reusable in generating the requested HTML page. If the key and/or input data of the matched portions stored in memory are not same as the key and/or input data of the generated portions (i.e., determination block **1814**="No"), the browser may process the generated DOM tree and perform the computations in block **1808**. If the keys and/or input data match (i.e., determination block **1814**="Yes") the browser may determine if all the necessary computations have been computed or recalled from memory in determination block **1816**. If all computations are not complete (i.e., determination block **1816**="No"), the browser may parse another section of the HTML code to generate additional portions of the DOM tree by returning to block **1804**. If all the computations are complete (i.e., determination block **1816**="Yes"), the browser may validate the data and compose the page for rendering in block **1818**, and display the page on an electronic display of a computing device in block **1820**.

FIG. **19** illustrates an alternative aspect method **1900** for creating, processing, storing and/or retrieving portions of a DOM tree on subsequent executions of the browser. In method **1900** in block **1902**, the browser may receive HTML code from a cache memory and/or a remote server. In block **1904**, the browser may parse the received HTML and generate one or more portions of a DOM tree based on the received HTML. In block **1908**, the browser may process and compare the generated DOM tree portions to DOM trees stored in memory by executing threads/processes that implement iso-

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morphic algorithms to determine if portions of the generated DOM tree match (e.g., are structurally similar to) any portions of DOM trees stored in memory. If structurally similar and/or identical DOM tree portions (e.g., isomorphic portions) are not found in the cache memory, the browser may store the computations in memory indexed to a DOM tree using a data structures such as one of the example structures described above. If structurally similar and/or identical DOM tree portions (e.g., isomorphic portions) are found in memory, in determination block **1910** the browser may extract and/or retrieve the isomorphic portions from the cache memory and determine if the keys and/or data input values match. In various aspects, the DOM trees may be stored in a hash-table and/or hash-map such that the keys and/or input data will match whenever one or more portions of the compared DOM trees are determined to be isomorphic. In these aspects, block **1908** may be combined with determination block **1910** and block **1912**, as illustrated by block **1920**.

If it is determined that the keys and/or data input values of the generated portions of the DOM tree do not match any of the keys and/or data input values of portions of the DOM trees stored in the cache memory (i.e., determination step **1910**="No"), the browser may create, process, and/or store the generated portions by traversing the DOM tree and performing the associated calculations as described above in method **1700** with reference to FIG. **17**. If, on the other hand, one or more of DOM tree portions are determined to have matching keys and/or input values (i.e., determination step **1910**="Yes"), the browser may pull the values associated with the matching keys and/or input values from memory in block **1912**. In determination block **1914**, the pulled values (e.g., stored calculations retrieved from memory) may be validated using one or more known data and/or HTML validation schemes. If one or more of the validation schemes fails (i.e., determination block **1914**="No"), the browser may create, process, and store the generated portions of the HTML calculations by traversing the DOM tree and performing the associated calculations as described above in with method **1700** with reference to FIG. **17**. If the data is determined to be valid (i.e., determination block **1914**="Yes"), the browser may compose the page in block **1916**, and display the resultant HTML webpage on an electronic display in block **1918**.

FIG. **20** is a system block diagram of a mobile computing device suitable for use with any of the aspects. A typical mobile computing device **2000** may include a processor **2001** coupled to internal memory **2002**, a display **2003**, and to a speaker **2054**. Additionally, the mobile computing device **2000** may include an antenna **2004** for sending and receiving electromagnetic radiation that may be connected to a wireless data link and/or cellular telephone transceiver **2005** coupled to the processor **2001** and a mobile computing device **2024** coupled to the processor **2001**. Mobile computing device **2000** typically also include menu selection buttons or rocker switches **2008** for receiving user inputs.

The aspects described above may also be implemented within a variety of computing devices, such as a laptop computer **2100** as illustrated in FIG. **21**. Many laptop computers include a touch pad touch surface that serves as the computer's pointing device, and thus may receive drag, scroll, and flick gestures similar to those implemented on mobile computing devices equipped with a touch screen display. A laptop computer **2100** will typically include a processor **2101** coupled to volatile memory **2102** and a large capacity non-volatile memory, such as a disk drive **2103**. The computer **2100** may also include a floppy disc drive **2104** and a compact disc (CD) drive **2105** coupled to the processor **2101**. The computer device **2100** may also include a number of connec-

tor ports coupled to the processor **2101** for establishing data connections or receiving external memory devices, such as a USB or FireWire® connector sockets, or other network connection circuits **2106** for coupling the processor **2101** to a network. In a notebook configuration, the computer housing includes the touchpad **2107**, keyboard **2108**, and the display **2109** all coupled to the processor **2101**. Other configurations of computing device may include a computer mouse or trackball coupled to the processor (e.g., via a USB input) as are well known.

The processors **2001**, **2101** may be any programmable microprocessor, microcomputer or multiple processor chip or chips that can be configured by software instructions (applications) to perform a variety of functions, including the functions of the various embodiments described below. In some mobile receiver devices, multiple processors **2101** may be provided, such as one processor dedicated to wireless communication functions and one processor dedicated to running other applications. Typically, software applications may be stored in the internal memory **2002**, **2102**, **2103** before they are accessed and loaded into the processor **2001**, **2101**. The processor **2001**, **2101** may include internal memory sufficient to store the application software instructions.

The various illustrative logics, logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general-purpose processor may be a microprocessor, but, in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. Additionally, at least one processor may comprise one or more modules operable to perform one or more of the steps and/or actions described above.

Further, the steps and/or actions of a method or algorithm described in connection with the aspects disclosed herein may be embodied directly in hardware, in a software module executed by a processor, or in a combination of the two. A software module may reside in RAM memory, flash memory, ROM memory, EPROM memory, EEPROM memory, registers, a hard disk, a removable disk, a CD-ROM, or any other form of storage medium known in the art. An exemplary storage medium may be coupled to the processor, such that the processor can read information from, and write information to, the storage medium. In the alternative, the storage medium may be integral to the processor. Further, in some aspects, the processor and the storage medium may reside in an ASIC. Additionally, the ASIC may reside in a user terminal. In the alternative, the processor and the storage medium may reside as discrete components in a user terminal. Additionally, in some aspects, the steps and/or actions of a method or algorithm may reside as one or any combination or set of codes and/or instructions on a machine readable medium and/or computer readable medium, which may be incorporated into a computer program product.

In one or more aspects, the functions described may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored as one or more instructions or code on a non-

transitory computer-readable medium. Non-transitory computer-readable media include any form of computer storage media that facilitates transfer of a computer program from one place to another. A non-transitory storage medium may be any available media that can be accessed by a computer. By way of example, and not limitation, such non-transitory computer-readable media may include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that can be used to carry or store desired program code in the form of instructions or data structures and that can be accessed by a computer. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk and blu-ray disc where disks usually reproduce data magnetically, while discs usually reproduce data optically with lasers. Combinations of the above should also be included within the scope of non-transitory computer-readable media.

While the foregoing disclosure discusses illustrative aspects and/or embodiments, it should be noted that various changes and modifications could be made herein without departing from the scope of the described aspects and/or embodiments as defined by the appended claims. Furthermore, although elements of the described aspects and/or embodiments may be described or claimed in the singular, the plural is contemplated unless limitation to the singular is explicitly stated. Additionally, all or a portion of any aspect and/or embodiment may be utilized with all or a portion of any other aspect and/or embodiment, unless stated otherwise.

What is claimed is:

1. A method of rendering a page on a computing device, comprising:
  - receiving, in a processor of the computing device, a request to display a web page having a first uniform resource locator (URL);
  - receiving software code corresponding to the requested web page;
  - parsing the received software code to generate a document object model (DOM) tree;
  - determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees, wherein each of the plurality of DOM trees comprises relationship data for different instances of a page and each of the one or more portions of the particular stored DOM tree refers to one or more dynamic stored DOM portions that are unique to the different instances of the page;
  - retrieving from a memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree when it is determined that a portion of the generated DOM tree is isomorphic with one or more portions of the particular stored DOM tree, wherein the previously stored calculations used to process HTML code comprise one or more of parsing, formatting, and rendering web-based content for a second instance of the requested web page having a second URL that is different from the first URL, wherein the second web page is different from the requested web page;
  - retrieving the particular stored DOM tree that was determined to comprise one or more portions that are isomorphic with the portion of the generated DOM tree;
  - composing the requested webpage using the retrieved HTML computations and the one or more portions of the

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retrieved particular stored DOM tree and the dynamically stored DOM-portions of the retrieved particular stored DOM tree; and  
 displaying the composed requested web page on an electronic display of the computing device.

5 2. The method of claim 1, wherein:  
 receiving software code corresponding to the requested web page comprises receiving HTML code corresponding to the requested web page; and  
 parsing the received software code to generate a document object model (DOM) tree comprises parsing the received HTML code to generate a DOM tree.

10 3. The method of claim 2, wherein determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises comparing the generated DOM tree with DOM tree structures of the particular stored DOM tree using a tree isomorphism comparison algorithm.

15 4. The method of claim 2, wherein determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree has a structure that is identical to one or more portions of the particular stored DOM.

20 5. The method of claim 2, wherein determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree is structurally similar to one or more portions of the particular stored DOM tree.

25 6. The method of claim 2, further comprising determining whether key values and input values used to create computation results of the particular stored DOM tree-equal key values and input values of the generated DOM tree,  
 wherein retrieving from the memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree is performed only when it is determined that the key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree.

30 7. The method of claim 2, wherein retrieving from the memory the previously stored HTML calculations associated with isomorphic portions of the particular stored DOM tree comprises accessing the memory storing the computation results of the portions of the DOM trees such that they are indexed by a computed hash value based on a DOM sub-tree structure corresponding to portions of the DOM trees.

35 8. The method of claim 2, further comprising:  
 completing HTML code computations for the generated DOM tree when it is determined that the generated DOM tree is not isomorphic with any of the one or more portions of the particular stored DOM tree; and  
 storing the results of the HTML computations indexed with the generated DOM tree in the memory.

40 9. The method of claim 8, wherein storing the generated DOM tree comprises storing at least a portion of the generated DOM tree in a key-value data structure in which DOM tree elements are stored in association with the corresponding HTML computation results.

45 10. The method of claim 9, wherein the key-value data structure comprises a hash-map data structure.

50 11. The method of claim 10, wherein retrieving previously stored calculations from the memory comprises evaluating hash-keys associated with nodes of the stored DOM tree that are isomorphic with the portion of the generated DOM tree.

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12. A computing device, comprising:  
 a memory;  
 a processor coupled to the memory;  
 means for receiving a request to display a web page having a first uniform resource locator (URL);  
 means for receiving software code corresponding to the requested web page;  
 means for parsing the received software code to generate a document object model (DOM) tree;  
 means for determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees, wherein each of the plurality of DOM trees comprises relationship data for different instances of a page and each of the one or more portions of the particular stored DOM tree refers to one or more dynamic stored DOM portions that are unique to the different instances of the page;  
 means for retrieving from a memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree when it is determined that a portion of the generated DOM tree is isomorphic with one or more portions of the particular stored DOM tree, wherein the previously stored calculations used to process HTML code comprise one or more of parsing, formatting, and rendering web-based content for a second instance of the requested web page having a second URL that is different from the first URL, wherein the second web page is different from the requested web page;  
 means for retrieving the particular stored DOM tree that was determined to comprise one or more portions that are isomorphic with the portion of the generated DOM tree;  
 means for composing the requested webpage using the retrieved HTML computations and the one or more portions of the retrieved particular stored DOM tree and the dynamically stored DOM portions of the retrieved particular stored DOM tree; and  
 means for displaying the composed requested web page on an electronic display.

13. The computing device of claim 12, wherein:  
 means for receiving software code corresponding to the requested web page comprises means for receiving HTML code corresponding to the requested web page; and  
 means for parsing the received software code to generate a document object model (DOM) tree comprises means for parsing the received HTML code to generate a DOM tree.

14. The computing device of claim 13, wherein means for determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises means for comparing the generated DOM tree with DOM tree structures of the particular stored DOM tree using a tree isomorphism comparison algorithm.

15. The computing device of claim 13, wherein means for determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises means for determining whether the portion of the generated DOM tree has a structure that is identical to one or more portions of the particular stored DOM tree.

16. The computing device of claim 13, wherein means for determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored

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DOM tree from a plurality of stored DOM trees comprises means for determining whether the portion of the generated DOM tree is structurally similar to one or more portions of the particular stored DOM tree.

17. The computing device of claim 13, further comprising means for determining whether key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree,

wherein means for retrieving from the memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree-comprises means for retrieving the stored HTML calculations associated with isomorphic portions of the particular stored DOM tree only when it is determined that the key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree.

18. The computing device of claim 13, wherein means for retrieving from the memory the previously stored HTML calculations associated with isomorphic portions of the particular stored DOM tree comprises means for accessing the memory storing the computation results of the portions of the DOM trees such that they are indexed by a computed hash value based on a DOM sub-tree structure corresponding to portions of the DOM trees.

19. The computing device of claim 13, further comprising: means for completing HTML code computations for the generated DOM tree when it is determined that the generated DOM tree is not isomorphic with any of the one or more portions of the particular stored DOM tree; and means for storing the results of the HTML computations indexed with the generated DOM tree in the memory.

20. The computing device of claim 19, wherein means for storing the generated DOM tree comprises means for storing at least a portion of the generated DOM tree in a key-value data structure in which DOM tree elements are stored in association with the corresponding HTML computation results.

21. The computing device of claim 20, wherein means for storing at least a portion of the generated DOM tree in a key-value data structure comprising means for storing at least a portion of the generated DOM tree in a hash-map data structure.

22. The computing device of claim 21, wherein means for retrieving previously stored calculations from the memory comprises means for evaluating hash-keys associated with nodes of the stored DOM tree that are isomorphic with the portion of the generated DOM tree.

23. A computing device, comprising:  
a memory; and

a processor coupled to the memory, wherein the processor is configured with processor executable instructions to perform operations comprising:

receiving a request to display a web page having a first uniform resource locator (URL);

receiving software code corresponding to the requested web page;

parsing the received software code to generate a document object model (DOM) tree;

determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees, wherein each of the plurality of DOM trees comprises relationship data for different instances of a page and each of the one or more por-

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tions of the particular stored DOM tree refers to one or more dynamic stored DOM portions that are unique to the different instances of the page;

retrieving from a memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree when it is determined that a portion of the generated DOM tree is isomorphic with one or more portions of the particular stored DOM tree, wherein the previously stored calculations used to process HTML code comprise one or more of parsing, formatting, and rendering web-based content for a second instance of the requested web page having a second URL that is different from the first URL, wherein the second web page is different from the requested web page;

retrieving the particular stored DOM tree that was determined to comprise one or more portions that are isomorphic with the portion of the generated DOM tree; composing the requested webpage using the retrieved HTML computations and the one or more portions of the retrieved stored particular stored DOM tree and the dynamically stored DOM portions of the retrieved particular stored DOM tree; and

displaying the composed requested web page.

24. The computing device of claim 23, wherein the processor is configured with processor-executable instructions to perform operations such that:

receiving software code corresponding to the requested web page comprises receiving HTML code corresponding to the requested web page;

parsing the received software code to generate a document object model (DOM) tree comprises parsing the received HTML code to generate a DOM tree.

25. The computing device of claim 24, wherein the processor is configured with processor-executable instructions such that determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises comparing the generated DOM tree with DOM tree structures of the particular stored DOM tree using a tree isomorphism comparison algorithm.

26. The computing device of claim 25, wherein the processor is configured with processor-executable instructions such that determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree has a structure that is identical to one or more portions of the particular stored DOM tree.

27. The computing device of claim 25, wherein the processor is configured with processor-executable instructions such that determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree is structurally similar to one or more portions of the particular stored DOM tree.

28. The computing device of claim 25, wherein the processor is configured with processor-executable instructions to perform operations further comprising determining whether key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree,

wherein the processor is configured with processor-executable instructions such that retrieving from the memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the

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particular stored DOM tree is performed only when it is determined that the key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree.

29. The computing device of claim 25, wherein the processor is configured with processor-executable instructions such that retrieving from the memory the previously stored HTML calculations associated with isomorphic portions of the particular stored DOM tree comprises accessing the memory storing the computation results of the portions of the DOM trees such that they are indexed by a computed hash value based on a DOM sub-tree structure corresponding to portions of the DOM trees.

30. The computing device of claim 25, wherein the processor is configured with processor-executable instructions to perform operations further comprising:

- completing HTML code computations for the generated DOM tree when it is determined that the generated DOM tree is not isomorphic with any of the one or more portions of the particular stored DOM tree; and
- storing the results of the HTML computations indexed with the generated DOM tree in the memory.

31. The computing device of claim 30, wherein the processor is configured with processor-executable instructions such that storing the generated DOM tree comprises storing at least a portion of the generated DOM tree in a key-value data structure in which DOM tree elements are stored in association with the corresponding HTML computation results.

32. The computing device of claim 31, wherein the processor is configured with processor-executable instructions such that the key-value data structure comprises a hash-map data structure.

33. The computing device of claim 32, wherein the processor is configured with processor-executable instructions such that retrieving previously stored calculations from the memory comprises evaluating hash-keys associated with nodes of the stored DOM tree that are isomorphic with the portion of the generated DOM tree.

34. A non-transitory computer readable storage medium having stored thereon processor-executable software instructions configured to cause a processor of a computing device to perform operations comprising:

- receiving a request to display a web page having a first uniform resource locator (URL);
- receiving software code corresponding to the requested web page;
- parsing the received software code to generate a document object model (DOM) tree;
- determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees, wherein each of the plurality of DOM trees comprises relationship data for different instances of a page and each of the one or more portions of the particular stored DOM tree refers to one or more dynamic stored DOM portions that are unique to the different instances of the page;

- retrieving from a memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree when it is determined that a portion of the generated DOM tree is isomorphic with one or more portions of the particular stored DOM tree, wherein the previously stored calculations used to process HTML code comprise one or more of parsing, formatting, and rendering web-based content for a second instance of the requested

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web page having a second URL that is different from the first URL, wherein the second web page is different from the requested web page;

- retrieving the particular stored DOM tree that was determined to comprise one or more portions that are isomorphic with the portion of the generated DOM tree;
- composing the requested webpage using the retrieved HTML computations and the one or more portions of the retrieved particular stored DOM tree and the dynamically stored DOM-portions of the retrieved particular stored DOM tree; and
- displaying the composed requested web page on an electronic display.

35. The non-transitory computer readable storage medium of claim 34, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that:

- receiving software code corresponding to the requested web page comprises receiving HTML code corresponding to the requested web page; and
- parsing the received software code to generate a document object model (DOM) tree comprises parsing the received HTML code to generate a DOM tree.

36. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that determining whether a portion of the generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises comparing the generated DOM tree with DOM tree structures of the particular stored DOM tree using a tree isomorphism comparison algorithm.

37. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree has a structure that is identical to one or more portions of the particular stored DOM tree.

38. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that determining whether a portion of generated DOM tree is isomorphic with one or more portions of a particular stored DOM tree from a plurality of stored DOM trees comprises determining whether the portion of the generated DOM tree is structurally similar to one or more portions of the particular stored DOM tree.

39. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations further comprising determining whether key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree,

- wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that retrieving from the memory previously stored HTML calculations used to process HTML code associated with isomorphic portions of the particular stored DOM tree is performed only when it is determined that the key values and input values used to create computation results of the particular stored DOM tree equal key values and input values of the generated DOM tree.



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40. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that retrieving from the memory the previously stored HTML calculations associated with isomorphic portions of the particular stored DOM tree comprises accessing the memory storing the computation results of the portions of the DOM trees such that they are indexed by a computed hash value based on a DOM sub-tree structure corresponding to portions of the DOM trees.

41. The non-transitory computer readable storage medium of claim 35, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations further comprising:

completing HTML code computations for the generated DOM tree when it is determined that the generated DOM tree is not isomorphic with any of the one or more portions of the particular stored DOM tree; and storing the results of the HTML computations indexed with the generated DOM tree in the memory.

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42. The non-transitory computer readable storage medium of claim 41, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that storing the generated DOM tree comprises storing at least a portion of the generated DOM tree in a key-value data structure in which DOM tree elements are stored in association with the corresponding HTML computation results.

43. The non-transitory computer readable storage medium of claim 42, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that the key-value data structure comprises a hash-map data structure.

44. The non-transitory computer readable storage medium of claim 43, wherein the stored processor-executable instructions are configured to cause a processor of a computing device to perform operations such that retrieving previously stored calculations from the memory comprises evaluating hash-keys associated with nodes of the stored DOM tree that are isomorphic with the portion of the generated DOM tree.

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